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LIST OF ILLUSTRATIONS

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तदेकोऽवशिष्टः शिवः केवलोऽहम् ।

सोऽहम् ।

YOGA-MÎMÂṄSÂ

VOL. V JANUARY, 1934 NO. 1

Editorial Notes

MAY the Maker of all make this journal a success. Blessed is the name of the Lord. May He bless the workers of the Âśrama with a happy and prosperous career as servants of the world which is only the Lord Himself objectified. May He, that has created us in His infinite wisdom, lead us to the light that is beyond all darkness.

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WE have great pleasure in presenting to our subscribers this first number of VOLUME V. We feel great satisfaction at having been able to complete the first four volumes of this journal and to start the publication of the fifth. This literary and scientific work has become possible largely for the steady support our subscribers have given us, and with deep sense of gratitude we offer our heart-felt thanks to them. Our subscribers may rest assured that we shall spare no pains in serving them at least as faithfully as we have been doing up to now, and make this volume as interesting and instructive as any of its predecessors.

It is, however, to be remembered that the scientific research work which is being published in this journal and which is mainly responsible for making it so authoritative and attractive, would not have become possible simply for the

support of the subscribers. It is the patronage of some of the ruling and merchant princes that is enabling us to conduct our researches. We feel deeply indebted to these patrons of ours and we strongly hope that our readers will join us in offering them the warmest of thanks for thus promoting the cause of scientific Yoga for the good of humanity.

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WE have also to record our heart-felt thanks to the famous Yale University of America for feeling interested in Yoga. Early in 1932, this American University sent its research fellow, Mr. K. T. Behanan, to India for studying Yoga on the spot. Mr. Behanan stayed at the *Kaivalyadhâma* for nearly a year and tried his best to learn as much of Yoga as he could in a year's time. He has now returned to America. The sense of gratitude felt both by Mr. Behanan and the Yale University for the facilities given to Mr. Behanan at the Âśrama, has been recorded in an official letter sent to us by Prof. Roswell P. Angier, the Chairman of the Department of Psychology. Our readers will find this letter published in the *Miscellaneous Section* of this number.

It is to be noted that the Yale University has already started scientific research in the field of Yoga just after the fashion of the *Kaivalyadhâma*, with the help of Mr. Behanan. The co-operation thus started between our Âśrama and the American University, is very likely to lead to further developments and may be taken as a harbinger of the dawn of that era which will witness the happy co-ordination of Eastern and Western civilizations.

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As mentioned in the last number of this journal, Prâṇâyâma will continue to be the principal theme of this volume. Our readers will do well to remember that the subject of Prâṇâyâma occupies a very important position in the study of Yoga. Prâṇâyâma may be rightly said to be the connecting link between the body and the mind. The higher stages of Yoga, namely, Pratyâhâra, Dhâraṇâ, Dhyâna and Samâdhi are

so closely connected with Prâṇâyâma, that a thorough understanding of the physiology of Prâṇâyâma is absolutely essential for understanding the psycho-physiological aspects of these stages. It is because of this supreme importance of the physiology of Prâṇâyâma, that we are devoting so much attention to the subject. Hereafter we will be taking our readers into the finer studies of physiology in general and the physiology of nerves in particular. We have, therefore, to request them to pay closer attention to the study of this journal than what has been given to it up to now.

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OUR readers need have no misgivings regarding their capacity to understand these finer details of physiology. From the very beginning we have visualized our reader as a smart matriculate, and have ever endeavoured to make things easily intelligible to such a reader. So whenever there is any difficulty in following any of our discussions, our readers should take it for granted that the difficulty is due to their *not having digested* the scientific material published in the previous volumes of the journal. Any reader that thoroughly studies *Yoga-Mîmâṅsâ* from the very beginning, will find every subsequent number as easy to read and understand as a novel.

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DIGESTING so much scientific material does mean considerable labour. But this labour will give its own reward. It will give every reader a clear and intimate knowledge of the vital processes working in the human body and will enable him to intelligently understand the scientific bearings not only of Yogic exercises, but of physical exercises in general, and also of any physical activities that he undertakes in his life. It will prepare him to follow the psycho-physiological discussions that will come up in this journal later on, and will give him an intelligent grasp of the stages of Pratyâhâra, Dhâraṇâ, Dhyâna and Samâdhi. Thus it will be seen that no student of Yoga can afford to grudge spending time and energy over the study of the scientific information that is being supplied in this journal. Nor is there any reason for anybody to despair over the study

of *Yoga-Mîmâṅsâ.* As stated above a systematic study of the journal from the beginning, will make its reading as enjoyable as that of a novel.

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EVEN the practical students of Yoga should find the study of *Yoga-Mîmâṅsâ* indispensable. It has been invariably found that the theoretical knowledge of an exercise doubly strengthens the faith of a student of Yoga. He is also able to discuss successfully the merits of a particular exercise with people who are prejudiced against Yoga and who try to infect others with their prejudices. How we wish that every reader of *Yoga-Mîmâṅsâ* should be a centre of Yogic activity. He should not only try to develop himself physically and spiritually, but should try to lead others along the path of Yoga as best as he can.

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DOUBTS expressed in this number regarding the accuracy of Haldane's methods of sampling the alveolar air, have been raised in our mind during our experimental work in the laboratory. We have expressed them here with a view to seek light from those scientists that may be interested in this method. We shall, therefore, thankfully receive any criticism that may be sent to us in this connection.

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WE beg to draw our reader's attention to the needs of the Âśrama published in the *Miscellaneous Section.* Therein will also be found a Classification of Donors. In the next number we shall publish lists of our Patrons, Fellows and Permanent Members, and give details of our needs. To-day we wish to content ourselves with telling our readers that the Âśrama, like every other growing charitable institution, needs large funds and that we appeal to our readers' generosity for help.

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MAY the Lord that enabled us to found the Âśrama, give us strength enough to carry on its work! May He ever widen the circle of our sympathizers and thus allow us to serve Him and His children to the best of our ability!

SYSTEM OF TRANSLITERATION

Letters, their sounds, and a description of these sounds :—

ॐ (ओम्)	AUM	Pronounce	'au'	like	'o'	in	'home'.
अ	A	,,	'a'	,,	'u'	,,	'but'.
आ	Â	,,	'â'	,,	'a'	,,	'far'.
इ	I	,,	'i'	,,	'i'	,,	'pin'.
ई	Î	,,	'î'	,,	'ee'	,,	'feel'.
उ	U	,,	'u'	,,	'u'	,,	'fulsome'.
ऊ	Û	,,	'û'	,,	'oo'	,,	'wool'.
ऋ	ṚI	,,	'ṛi'	,,	'rö'	,,	German.
ॠ	ṚÎ	,,	'ṛî'	,,	,,	,,	,, with a strong accent.
ऌ	ḶI	,,	'ḷi'	,,	'lö'	,,	German.
ए	E	,,	'e'	,,	'a'	,,	'fate'.
ऐ	AI	,,	'ai'	,,	'ai'	,,	'aisle' but not drawled out.
ओ	O	,,	'o'	,,	'o'	,,	'over'.
औ	AU	,,	'au'	,,	'ou'	,,	'ounce' but not drawled out.
क	KA	,,	'k'	,,	'k'	,,	'kill'.
ख	KHA	,,	'kh'	,,	'kh'	,,	'ink-horn' or like 'ch' in 'Loch' (Scottish).
ग	GA	,,	'g'	,,	'g'	,,	'girl'.
घ	GHA	,,	'gh'	,,	'gh'	,,	'log-house' or 'ghee'.
ङ	ÑA	,,	'ñ'	,,	'n'	,,	'king' or 'ink'.
च	CHA	,,	'ch'	,,	'ch'	,,	'church'.
छ	CHHA	,,	'chh'	,,	the second	'ch' in 'churchill'.	
ज	JA	,,	'j'	,,	'j'	in	'join'.
झ	JHA	,,	'jh'	,,	palatal 'z' as in 'azure'.		
ञ	N'A	,,	'n''	,,	'n'	in	'pinch'.

ट	ṬA	Pronounce	'ṭ'	like	't'	in	'tub'.
ठ	ṬHA	,,	'ṭh'	,,	'th'	,,	'pot-house'.
ड	ḌA	,,	'ḍ'	,,	'd'	,,	'dog'.
ढ	ḌHA	,,	'ḍh'	,,	'dh'	,,	'mad-house'.
ण	ṆA	,,	'ṇ'	,,	'n'	,,	'splinter' or 'and'.
त	TA	,,	't'	,,	dental 't' as in 'thin' or like the French 'T'.		
थ	THA	,,	'th'	,,	'th'	in	'thunder'.
द	DA	,,	'd'	,,	'th'	,,	'then'.
ध	DHA	,,	'dh'	,,	'th'	,,	'this'.
न	NA	,,	'n'	,,	'n'	,,	'no'.
प	PA	,,	'p'	,,	'p'	,,	'paw'.
फ	PHA	,,	'ph'	,,	'ph'	,,	'top-heavy' or 'gh' in 'laugh'.
ब	BA	,,	'b'	,,	'b'	,,	'balm'.
भ	BHA	,,	'bh'	,,	'bh'	,,	'hob-house'.
म	MA	,,	'm'	,,	'm'	,,	'mat'.
य	YA	,,	'y'	,,	'y'	,,	'yawn'.
र	RA	,,	'r'	,,	'r'	,,	'rub'.
ल	LA	,,	'l'	,,	'l'	,,	'lo'.
व	VA	,,	'v'	,,	'w'	,,	'wane'.
श	ŚA	,,	'ś'	,,	'sh'	,,	'ashes'.
ष	SHA	,,	'sh'	,,	a strong lingual with rounded lips.		
स	SA	,,	's'	,,	's'	in	'sun'.
ह	HA	,,	'h	,,	'h'	,,	'hum'
ळ	ḶA	A dento-lingual pronounced with a little rounding of lips.					

Nasalized म् as in संयम—Ṃ; Nasalized म् as in संलग्न—M̃ ;
,, ,, ,, ,, संवाद—M̱; ,, ,, ,, ,, संहिता—Ṁ ;
Nasalized न् as in मीमांसा—Ṅ ; Visarga—Ḥ.

The Scientific Section

N. B.—Those of our readers that claim no acquaintance with Anatomy and Physiology will do well to read the Semi-Scientific Section first.

ALVEOLAR AIR COMPOSITION EXPERIMENTS

INTRODUCTION

J. S. HALDANE has laid so much stress on the composition of alveolar air and especially on the CO_2 percentage in it, that no student that wants to investigate Yogic exercises in Prâṇâyâma, can afford to lose sight of this subject. Hence we have been studying the question of the composition of the alveolar air and its bearings on Prâṇâyâma. Our research work is still in progress and it will take a long time before we can finally formulate any theories of our own. In the meantime it is proposed to publish our research work bit by bit, so that we can receive from the scientific world criticisms which are bound to be of great help to us in our work of Yogic investigation. In this number only eight experiments are being published. Even when we do not want to arrive at any generalizations on the strength of these experiments, it will be worth our while to examine the results and see how far they agree or disagree with the results already obtained by physiologists in the West.

These eight experiments have been done with a view to verify the general conclusions of Haldane in which he says that the deeper parts of a very deep breath have *exactly the same* composition as the middle parts.

In the collection of the alveolar air and in getting a sample from it of the deeper and the deepest parts, we have used a different method from the one devised by Haldane and Priestley. In our note on the 'Alveolar Air' in the *Semi-Scientific Section* of this number, we will discuss though briefly, why we find Haldane's method to be possibly unsatisfactory, and also how our method is calculated to give more accurate results. In the experiments under description, we have used the last 400 to 500 c.c. approximately of the deepest expiration

for our sample, the first 200 to 250 c.c. representing the deeper parts of the alveolar air and the other 200 to 250 c.c. supplying us with the deepest parts of the same. We believe that physiologists are agreed in admitting that the last 500 c.c. of the deepest expiration would surely belong to the alveolar part of the expired air.

There is one point of real importance regarding the sampling method which we have followed in the experiments under discussion, which requires some explanation. Haldane and the physiologists of the opposite school, are agreed in saying that during the process of expiration the CO_2 percentage in the alveolar air would increase. During rest, according to Haldane, this increase would take place at the rate of 0·1 per second. Now in our experiments the middle part of the alveolar air was collected in the sixth second whereas the last part was collected in the seventh second. That means the second sample was collected one second later than the first sample. Had the seventh second's sample been collected in the sixth second, that is, one second earlier, it would have shown a smaller percentage of CO_2. Hence for the sake of accuracy, the CO_2 percentages found in the last samples of the alveolar air, must be shown 0·1 per cent. lower than what they have been shown in the tables. As we are going to point out later on this deduction of 0·1 per cent. does not at all materially affect our position. On the contrary it goes against Haldane's proposition.

The proposition that every second of expiration would add 0·1 per cent. to the CO_2 in the alveolar air, is to be received with great caution, however. In this connection we might refer our readers with great advantage to the experimental work published in the fourth number of the last volume. There we have determined CO_2 percentages *in the expired air*, the process of expiration lasting over different

time units, such as 7″, 14″, 21″ and 28 seconds. The CO_2 percentages in the expired air for these time units were found respectively to be 5·22, 5·38, 5·69 and 5·95, which fail to support the proposition of Haldane.

It is true that the CO_2 determinations, referred to in the last paragraph, were done with the entire expired air and not with the alveolar parts of it. According to our view, however, this does not matter. A reference to the table given at the end of this introduction, will show[1] that in our experimental work we find greater CO_2 concentration in the expired air as a whole than in the alveolar part of it. Hence delayed expiration, if it is to show a higher percentage of CO_2, would show it in the entire expired air rather than in the alveolar part of it only.

Having thus discussed one possible objection against our method of securing the necessary samples, we shall proceed to study some of the results of our experimental work, trying to see how far they agree or disagree with Haldane's conclusion under discussion.

For the eight experiments published in this *Section*, altogether four subjects were examined, all of them being examined twice for the same type of sample and two of them were examined four times for similar samples. The results of the first examination were entered in the tables under the first attempt and the results of the second examination under the second attempt. In the case of the two subjects that underwent four examinations, the results of the third and fourth examinations were shown under the first attempt and second attempt respectively, they being treated as altogether different subjects for the third and the fourth examinations. Thus A and B were examined four times. But their results of the first two examinations were shown against their original names,

1 Compare columns 2 and 3.

whereas the results of the third and fourth examinations were shown against the names A′ and B′ respectively. There was sound reason for treating them virtually as different subjects. The first two examinations and the last two examinations were instituted at an interval of about three weeks, that is, possibly under different metabolic conditions.[1] Generally speaking the first and the second tests were carried out on successive mornings, all the first tests of a subject being instituted on one and the same morning, and the second tests on the next morning.

But the question as to whether the tests were carried out on successive mornings or otherwise, is immaterial to us so far as the present experiments are concerned. Here our comparisons lie between the middle parts and the deepest parts of the alveolar air. We have taken good care to see that these two sets of parts were always secured in the case of every subject not only on the same morning, but also from the same deep expiration, as was absolutely necessary for getting accurate results.[2]

The first experiment was done for finding out the CO_2 percentage in the normal expiration of the subjects whereas the second was done for determining the same in the deepest expiration at the end of deepest inspiration. Experiments III to VIII were performed for comparing the CO_2 percentages in the middle and the last parts of the alveolar air of three different types—one, alveolar air collected from the deepest expiration at the end of normal inspiration; another, alveolar air from the deepest expiration at the end of normal expiration; and the third, alveolar air from the deepest expiration at the end of deepest inspiration. Table XII shows us the comparison between the CO_2 percentages in the middle or the last but one

1 This is true especially in the case of the subject appearing as B and B′. When he was examined as B, his health was quite indifferent.

2 Variety in the metabolic activities of the different subjects has yielded more reliable *averages*.

part and the deepest or the last part of the alveolar air of the first type, that is, alveolar air collected from the deepest expiration at the end of normal inspiration. This comparison shows that in five cases out of six, the middle part contains a higher percentage of CO_2 than the last part, in one case the difference amounting to as much as 1·45 per cent.! If we lower down the percentages in the second column because of one second's delay in collecting the sample, the contrast between the two sets of percentages becomes still more striking. Table XI presents us a comparison of the CO_2 percentages in the middle and the deepest parts of the alveolar air of the second type, that is, alveolar air collected from the deepest expiration at the end of normal expiration. Here also in five cases out of six the middle parts contain a higher percentage of CO_2 than the deepest parts. The consideration of one second's delay in collecting the deepest part, would again make the comparison still more striking. Table X gives us somewhat different results. Here the middle part shows a higher percentage of CO_2 than the deepest part, only in two cases out of six. This difference may be due to the fact that this collection of alveolar air was made from the deepest expiration after the deepest inspiration and not from the deepest expiration after normal inspiration or expiration.

These comparisons very clearly point out that the middle and the deepest parts of the alveolar air are not necessarily uniform in composition. The differences tabulated in the three tables under reference may not appear significant to an unscientific mind. But in examining Haldane's theories we have to take account of differences as small as 0·2 percent., because according to him that much difference in the CO_2 percentage in the alveolar air would considerably affect the process of respiration.

In discussing Table XI, we have considered the CO_2 percentage in the last part of the deepest expiration after normal expiration, as the CO_2 percentage in the alveolar air. We

have done a similar thing in our discussion on Table XII. Now it may be pointed out that the CO_2 percentage in the alveolar air is to be determined by getting an average of the CO_2 percentages obtained by examining the deepest parts of deep expirations at the end of both normal expiration and normal inspiration. In Table XIII we have worked out CO_2 percentages in the deepest part of the alveolar air from two averages of CO_2 percentages, one obtained from the deepest expiration at the end of normal inspiration, as in Table VIII, and the other obtained from the deepest expiration at the end of normal expiration, as in Table VI. In Table XIV we have done a similar thing for the middle parts of the alveolar air. In Table XV these mean CO_2 percentages of the middle parts and the deepest parts of the alveolar air, are compared. Here in all the six cases out of six, the middle parts show a higher percentage of CO_2 than the deepest parts!

Thus we find that the experiments set forth in this number do not at all support the proposition that the middle parts and the deepest parts of the alveolar air are uniform in composition.

Our readers may collect some interesting information from the table printed on the next page. We wish to draw their attention especially to the fact that the CO_2 percentage in the alveolar air collected from the deepest expiration at the end of the deepest inspiration, is found to be lower than the CO_2 percentages in the whole expired air collected from the deepest expiration at the end of deepest inspiration.

We wish also to request our readers to institute a comparison between columns 5 and 6 of the table printed on p. 15. Column 5 tabulates the inspiratory samples whereas column 6 the corresponding expiratory samples. According to Haldane the inspiratory samples show a lower percentage of CO_2 than the expiratory samples.[1] Out of the six comparisons which our readers will make, five comparisons go against Haldane.

1 Another of Haldane's four conclusions which we will single out in the *Semi-Scientific Section* for being discussed in this journal at present.

Some Interesting Results in CO_2 Percentages

Subject	CO_2 percentage in normal expiration	CO_2 percentage in deepest expiration at the end of deepest inspiration	CO_2 percentage in last part of deepest expiration at the end of deepest inspiration	CO_2 percentage in last part of deepest expiration at the end of normal inspiration	CO_2 percentage in last part of deepest expiration at the end of normal expiration
A	2·25	4·83	2·63	1·7	2·6
B	4·05	4·63	4·6	3·23	2·45
A′	2·9	4·1	3·9	4·18	3·65
B′	3·95	4·7	3·5	3·7	2·65
C	3·53	4·88	5·15	4·85	4·53
D	3·0	4·58	4·03	3·33	3·28
Total	19·68	27·72	23·81	20·99	19·16
Final Average	3·28	4·62	3·97	3·5	3·19

ALVEOLAR AIR COMPOSITION EXPERIMENTS

EXPERIMENT I

OBJECT OF THE EXPERIMENT :—

The object of the experiment was to ascertain the average percentage of CO_2 present in the normal expiration of the subjects under examination, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number.

PREPARATION OF THE SUBJECTS :—

Four subjects were examined in this experiment. All of them were adults of ages varying from 25 to 35. The subjects A and B were examined twice and have been denoted as "A'" and "B'" for the second examination, the two examinations taking place at an interval of about three weeks. There was no special preparation of the subjects except that they were made to avoid all abnormal physical work during the days of experiments. They were put in a restful sitting position for at least five minutes before the expirations were collected.

THE APPARATUS :—

The apparatus used has been fully described in the *Semi-Scientific Section* of the second number of the last volume.

THE EXPERIMENT PROPER :—

The expired air of three normal exhalations in the case of each subject was collected in a rubber bag which was completely exhausted of ordinary air. Out of this a sample of 100 c.c. was analyzed for finding out CO_2 percentage present in it. Each subject made two attempts. The results are tabulated on the next page.

TABLE I

CO_2 Percentage in the Normal Expiration

Subject	1st Attempt	2nd Attempt	Average
A	2·4	2·1	2·25
B	3·7	4·4	4·05
A′	3·1	2·7	2·9
B′	3·9	4·0	3·95
C	3·25	3·8	3·53
D	3·3	2·7	3·0

Total 19·68 Final Average 3·28

EXPERIMENT II

OBJECT OF THE EXPERIMENT :—

The object of the experiment was to ascertain the average percentage of CO_2 present in the deepest exhalation at the end of deepest inhalation of the subjects under examination, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number.

PREPARATION OF THE SUBJECTS & THE APPARATUS :—

The subjects and the apparatus in this experiment were the same as in the previous experiment, the subjects being prepared in the same fashion as before.

THE EXPERIMENT PROPER :—

Each subject was made to inspire deeply, the process of inspiration being completed in seven seconds. Immediately at the end of inspiration the subject started expiration, this process being completed in seven seconds. The whole of the expired air was collected in a rubber bag as was done in the previous experiment. Out of this expired air a sample of 100 c.c. was analyzed for finding out the percentage of CO_2 present in it. Each subject was examined twice. The results are tabulated on the next page.

REMARKS :—

Remarks on the results of this and all other experiments appearing in this number, are to be found in the introduction to these experiments at the beginning of this *Section.*

TABLE II

CO_2 Percentage in Deepest Expiration at the End of Deepest Inspiration

Subject	1st Attempt	2nd Attempt	Average
A	5·05	4·6	4·83
B	3·95	5·3	4·63
A′	4·0	4·2	4·1
B′	4·7	...	4·7
C	5·0	4·75	4·88
D	4·5	4·65	4·58

Total 27·72 Final Average 4·62

EXPERIMENT III

OBJECT OF THE EXPERIMENT :—

The object of the experiment was to find out the average CO_2 percentage in the last but one part of the deepest expiration at the end of deepest inspiration of the subjects under examination, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number.

PREPARATION OF THE SUBJECTS & THE APPARATUS :—

The same as in the last two experiments.

THE EXPERIMENT PROPER :—

Each subject was made to inspire deeply in seven seconds. Immediately after the inspiration was completed the subject started deepest expiration with a view to distribute *almost* equally the process of exhalation over seven seconds. During the first five seconds the subject exhaled through the mouth so as to leave about 400 to 500 c.c. of supplemental air behind, which was to be expired during the next two seconds. The expiration of the sixth second was collected in a rubber bag which was immediately closed up, the expiration of the seventh second being collected in another bag of the same type for the succeeding experiment. Needless to say that the collections of the sixth and the seventh seconds were made through the mouth. The expiration of the sixth second which was analyzed in the present experiment measured approximately 200 to 250 c.c. Each subject made two attempts, these attempts being generally made on two successive days. The collected air was analyzed and the CO_2 percentage in it was ascertained. The results are tabulated on the next page.

TABLE III

CO_2 Percentage in Last But One Part of Deepest Expiration at the End of Deepest Inspiration

Subject	1st Attempt	2nd Attempt	Average
A	3·75	3·5	3·63
B	3·55	4·75	4·2
A′	2·3	3·4	2·85
B′	5·1	3·8	4·45
C	4·4	5·45	4·93
D	4·4	2·85	3·63

Total 23·69 Final Average 3·95

EXPERIMENT IV

OBJECT OF THE EXPERIMENT :—

The object of the experiment was to find out the average CO_2 percentage in the last part of the deepest expiration at the end of deepest inspiration of the subjects under examination, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number, and especially with the CO_2 percentage present in the last part of the deepest expiration at the end of normal inspiration.

PREPARATION OF THE SUBJECTS & THE APPARATUS :—

The same as before.

THE EXPERIMENT PROPER :—

This experiment was, properly speaking, a continuation of the last experiment. Therein we have stated that the expired air of the seventh second was collected in another rubber bag for this experiment, that air representing the last part of the deepest expiration at the end of deepest inspiration, and measuring 200 to 250 c.c. approximately. As in the previous experiment two attempts were made by each subject generally on two successive days. The collected air was analyzed as usual. The results are tabulated on the next page.

TABLE IV

CO_2 Percentage in the Last Part of Deepest Expiration at the End of Deepest Inspiration

Subject	1st Attempt	2nd Attempt	Average
A	2·25	3·0	2·63
B	5·05	4·15	4·6
A′	4·2	3·6	3·9
B′	4·9	2·0	3·5
C	4·65	5·65	5·15
D	4·4	3·65	4·03
		Total 23·81	Final Average 3·97

EXPERIMENT V

OBJECT OF THE EXPERIMENT :—

The object of the experiment was to find out the average CO_2 percentage in the last but one part of the deepest expiration at the end of normal expiration of the subjects under examination, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number, and especially with the CO_2 percentage present in the last part of the deepest expiration at the end of normal expiration.

PREPARATION OF THE SUBJECTS & THE APPARATUS :—

The same as before.

THE EXPERIMENT PROPER :—

Each subject was made to expire normally through the nose, the normal expiration covering about two seconds. At the end of the normal expiration the subject was made to exhale deeply through the mouth in such a way that the deepest exhalation would be completed in the next five seconds. The expiration of the sixth second was collected in a rubber bag. The expiration of the seventh and the last second being collected in another bag of the same type, and reserved for the next experiment. The expired air of the sixth second approximately measured 200 to 250 c.c. These sixth second collections were made twice in the case of each subject, generally speaking on two successive days. They were analyzed subsequently. The results have been tabulated on the next page.

TABLE V

CO_2 Percentage in Last But One Part of Deepest Expiration at the End of Normal Expiration

Subject	1st Attempt	2nd Attempt	Average
A	3·95	3·25	3·6
B	3·95	2·65	3·3
A′	4·4	4·1	4·3
B′	4·0	3·8	3·9
C	4·7	3·6	4·2
D	3·6	3·4	3·5

Total 22·8 Final Average 3·8

EXPERIMENT VI

OBJECT OF THE EXPERIMENT :—

The object of the experiment was to find out the average CO_2 percentage in the last part of the deepest expiration at the end of normal expiration of the subjects under examination, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number, and especially with the average CO_2 percentage present in the last but one part of the deepest expiration at the end of normal expiration as found out in the previous experiment.

PREPARATION OF THE SUBJECTS & THE APPARATUS :—

The same as before.

THE EXPERIMENT PROPER :—

During the last experiment the seventh second expired air was collected in separate rubber bags. These collections also measured from 200 to 250 c.c. each. They were analyzed subsequently. The results have been tabulated on the next page.

TABLE VI

CO_2 Percentage in the Last Part of Deepest Expiration at the End of Normal Expiration

Subject	1st Attempt	2nd Attempt	Average
A	2·9	2·3	2·6
B	2·8	2·1	2·45
A′	2·6	4·7	3·65
B′	3·5	1·8	2·65
C	4·0	5·05	4·53
D	3·5	3·05	3·28

Total 19·16 Final Average 3·19

EXPERIMENT VII

OBJECT OF THE EXPERIMENT :—

The object of the experiment was to find out the average CO_2 percentage in the last but one part of the deepest expiration at the end of normal inspiration, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number, and especially with the average CO_2 percentage present in the last part of the deepest expiration at the end of normal inspiration.

PREPARATION OF THE SUBJECTS & THE APPARATUS :—

The same as before.

THE EXPERIMENT PROPER :—

Each subject was made to complete his inspiration in the normal way. At the end of this normal inspiration, the subject was made to exhale deeply through the mouth in such a way that he would complete the process of deep exhalation in seven seconds. At the end of the fifth second the subject started collecting the expired air in a rubber bag. This was done for a second, the bag being immediately closed thereafter. The remaining expiration of the subject was completed in the seventh second, the exhaled air being collected in another bag of the same type. The exhalation of the sixth second measured about 200 to 250 c.c. It was subsequently analyzed. The results have been tabulated on the next page.

TABLE VII

CO_2 Percentage in Last But One Part of Deepest Expiration at the End of Normal Inspiration

Subject	1st Attempt	2nd Attempt	Average
A	2·3	3·0	2·65
B	5·0	4·35	4·68
A′	4·25	3·6	3·93
B′	4·6	5·35	4·98
C	5·4	5·0	5·2
D	4·0	3·6	3·8

Total 25·24 Final Average 4·21

EXPERIMENT VIII

OBJECTS OF THE EXPERIMENT :—

The object of the experiment was to find out the average CO_2 percentage in the last part of the deepest expiration at the end of normal inspiration, with a view to compare that percentage with the average CO_2 percentages present in the different samples of the alveolar air examined in the different experiments published in this number, and especially with the average CO_2 percentage present in the last but one part of the deepest expiration at the end of normal inspiration as found out in the previous experiment.

PREPARATION OF THE SUBJECTS & THE APPARATUS :—

The same as before.

THE EXPERIMENT PROPER :—

The collections of expired air secured in the last experiment during the seventh and the last second of deepest expiration at the end of normal inspiration, were used for this experiment. Each collection measured about 200 to 250 c.c. It was subsequently analyzed and the results have been tabulated on the next page.

TABLE VIII

CO_2 Percentage in the Last Part of Deepest Expiration at the End of Normal Inspiration

Subject	1st Attempt	2nd Attempt	Average
A	1·8	1·6	1·7
B	3·1	3·35	3·23
A′	3·65	4·7	4·18
B′	3·7	...	3·7
C	5·15	4·55	4·85
D	3·25	3·4	3·33

Total 20·99 Final Average 3·5

TABLE IX

Results of CO_2 Elimination Experiments at a Glance

CO_2 Percentage in the Normal Expiration	3·28
CO_2 Percentage in Deepest Expiration at the End of Deepest Inspiration	4·62
CO_2 Percentage in Last But One Part of Deepest Expiration at the End of Deepest Inspiration	3·95
CO_2 Percentage in the Last Part of Deepest Expiration at the End of Deepest Inspiration	3·97
CO_2 Percentage in Last But One Part of Deepest Expiration at the End of Normal Expiration	3·8
CO_2 Percentage in the Last Part of Deepest Expiration at the End of Normal Expiration	3·19
CO_2 Percentage in Last But One Part of Deepest Expiration at the End of Normal Inspiration	4·21
CO_2 Percentage in the Last Part of Deepest Expiration at the End of Normal Inspiration	3·5

TABLE X

Comparison of CO_2 Percentages in Last But One and the Last Parts of Deepest Expiration at the End of Deepest Inspiration

Subject	CO_2 percentage in last but one part	CO_2 percentage in the last part	Difference in CO_2 percentages in favour or against last but one part as compared with the last part
A	3·63	2·63	+ 1·0
B	4·2	4·6	− 0·4
A′	2·85	3·9	− 1·05
B′	4·45	3·5	+ 0·95
C	4·93	5·15	− 0·22
D	3·63	4·03	− 0·4

TABLE XI

Comparison of CO_2 Percentages in Last But One and the Last Parts of Deepest Expiration at the End of Normal Expiration

Subject	CO_2 percentage in last but one part	CO_2 percentage in the last part	Difference in CO_2 percentages in favour or against last but one part as compared with the last part
A	3·6	2·6	+ 1·0
B	3·3	2·45	+ 0·85
A′	4·3	3·65	+ 0·65
B′	3·9	2·65	+ 1·25
C	4·2	4·53	− 0·33
D	3·5	3·28	+ 0·22

TABLE XII

Comparison of CO_2 Percentages in Last But One and the Last Parts of Deepest Expiration at the End of Normal Inspiration

Subject	CO_2 percentage in last but one part	CO percentage in the last part	Difference in CO_2 percentages in favour or against last but one part as compared with the last part
A	2·65	1·7	+ 0·95
B	4·68	3·23	+ 1·45
A′	3·93	4·18	− 0·25
B′	4·98	3·7	+ 1·28
C	5·2	4·85	+ 0·35
D	3·8	3·33	+ 0·47

TABLE XIII

Average CO_2 Percentage in the Last or Deepest Part of the Alveolar Air

Subject	CO_2 percentage in the last part of deepest expiration at the end of normal expiration	CO_2 percentage in the last part of deepest expiration at the end of normal inspiration	Average CO_2 percentage in the last or deepest part of the alveolar air
A	2·6	1·7	2·15
B	2·45	3·23	2·84
A′	3·65	4·18	3·92
B′	2·65	3·7	3·18
C	4·53	4·85	4·69
D	3·28	3·33	3·31

Total 20·09 Final Average 3·35

TABLE XIV

Average CO_2 Percentage in Last But One or the Middle Part of the Alveolar Air

Subject	CO_2 percentage in last but one part of deepest expiration at the end of normal expiration	CO_2 percentage in last but one part of deepest expiration at the end of normal inspiration	Average CO_2 percentage in last but one or the middle part of the alveolar air
A	3·6	2·65	3·13
B	3·3	4·68	3·99
A′	4·3	3·93	4·12
B′	3·9	4·98	4·44
C	4·2	5·2	4·7
D	3·5	3·8	3·65

Total 24·03 Final Average 4·01

TABLE XV

Comparison of CO_2 Percentage in Last But One or the Middle Part and the Last or Deepest Part of the Alveolar Air

Subject	CO_2 percentage in last but one or the middle part of the alveolar air	CO_2 percentage in the last or deepest part of the alveolar air	Difference in CO_2 percentages in favour or against the middle part as compared with the deepest part
A	3·13	2·15	+ 0·98
B	3·99	2·84	+ 1·15
A′	4·12	3·92	+ 0·2
B′	4·44	3·18	+ 1·26
C	4·7	4·69	+ 0·01
D	3·65	3·31	+ 0·34

The Semi-Scientific Section

N. B.— The Director of the Kaivalyadhâma entreats every man of means to show his active sympathy for the Âśrama

ALVEOLAR AIR

PART I

In investigating the subject of Prâṇâyâma according to the modern sciences, we have largely to deal with the theories of respiration advanced by Western physiologists. For several decades these physiological scientists have spent their time, energy and intelligence on the problems of respiration; and even though some of the theories that were advocated in the beginning, had ultimately to be abandoned or modified substantially, to-day there are many theories over which the physiologists are unanimously agreed and which are accepted by them to be finally settled. When we started studying Prâṇâyâma physiologically, the question that confronted us was whether we should accept the Western theories of respiration without testing them in our laboratory before we applied them to Prâṇâyâma or whether we should examine these theories over again and then use them as the basis of our scientific study of Yogic respiration. As our readers must have seen by now our attitude towards the modern sciences is that of great respect. This attitude, however, never precluded us from verifying the Western theories before we used them for our researches in the field of different Yogic processes. We have been doing the same thing in our scientific study of Prâṇâyâma also.

The study of the alveolar air occupies a very prominent place in the domain of respiration. Many scientists have made this problem a subject of their special study; and after years of laborious and intelligent scientific work, have arrived at particular conclusions. Many of their theories directly bear on the question of Prâṇâyâma which we are trying to understand from the modern point of view. In this note we shall sum up some of these theories with a view to acquaint

our readers with what these scientists have to say in the matter. This statement will also enable our readers to follow[1] our experiments given in the *Scientific Section* of this and subsequent numbers intelligently, and to compare and contrast our results with the results of Western physiologists. For the present, however, we are not going to formulate any theories. It will require extensive research work before we can definitely confirm the Western theories of respiration or definitely advance any theories of our own. Our present purpose is to set forth the evidence that we are collecting in our laboratory and see whether this evidence supports the established theories of respiration or raises doubts about their accuracy.

The last two paragraphs are likely to lead our readers to think that the Western physiologists have tried experiments with Pranayamic respiration as it is practised in India by the students of Yoga, and have built their theories on the strength of the evidence collected from this experimental work. But that is not the case. So far as we know up to now no Pranayamic respiration has been subjected to scientific investigation in any of the genuine Western laboratories. But the physiologists of the West have so thoroughly explored the field of respiration in general, that they may be said to have examined almost all the phases of respiration except only those of Yogic respiration. All this excellent work has to be utilized in investigating the question of Prâṇâyâma. In doing this we may be required to contradict some of the accepted theories of the West.

Prâṇâyâma *on its physiological side* consists of various exercises, all directed towards the regulation of breath. Now an overwhelming majority of modern physiologists are agreed

1 A thorough grasp of our 'Note on Respiration' in *Volume III* and also of the notes on 'Pressure Changes in Prâṇâyâma' and 'Determination of CO_2 and O_2' in *Volume IV*, is essential for understanding the contents not only of this note, but the whole *Scientific* and *Semi-Scientific* portion of *Volume V*.

in coming to the conclusion that the CO_2 percentage[1] in the alveolar air is an extremely important factor in regulating our breath. Naturally one feels that the Pranayamic regulation of breath also must be determined by the percentage of CO_2 in the alveolar air. It is exactly this problem that we wish to investigate in this volume. Let us, therefore, first know what is alveolar air, how it is collected, how it is analyzed for finding out the CO_2 percentage in it, and what conclusions have the physiologists reached regarding the connection between this CO_2 percentage and the respiratory activity in general.

Alveoli (sing. *alveolus*, a small cavity) is another name of the air-cells of the lungs which cluster round the smallest bronchial tubes and into which the inspired air is ultimately received. They bar the further passage of the inhaled air, but allow across their thin walls an exchange of gases, so that the inspired air borrows CO_2 from the blood circulating around the alveoli, and gives O_2 to that blood in return. The air which is held in these air-cells or alveoli, is called the alveolar air. This simple definition is not, however, sufficient for us to understand the problem we are discussing. A detailed anatomical and physiological description is necessary for getting a clear grasp of that problem.

Let us first have anatomical details.

We have seen in the 'Note on Respiration' that all the alveoli developing themselves roundabout a fine bronchial tube, presenting the appearance of a bunch of grapes, go to form what is called an *ultimate lobule.* Several ultimate lobules constitute a *lobule*, and several such lobules are contained in a *lobe.* The right lung has three such lobes and

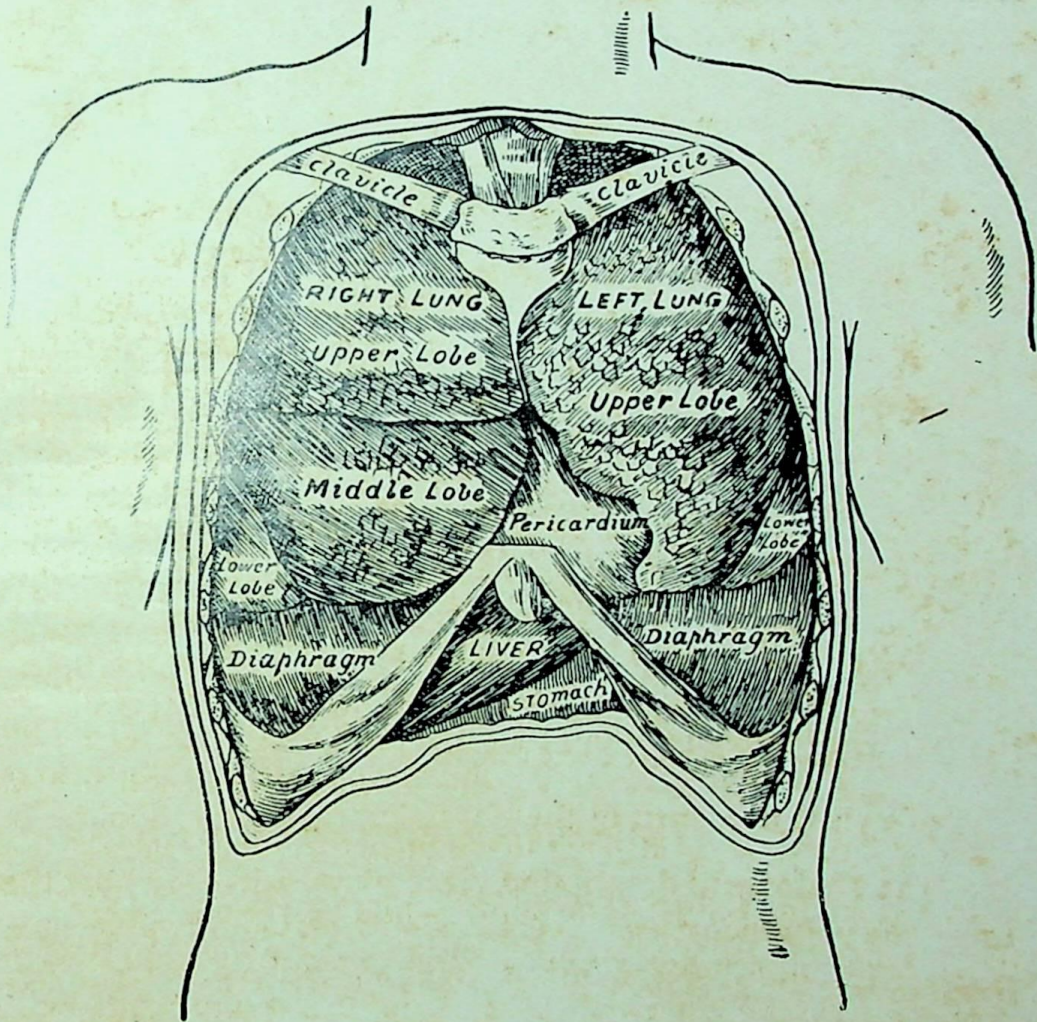
1 Accurately speaking it is the CO_2 *pressure* in the alveolar air and not its *percentage* that governs respiration. As we do not want to lead our readers into scientific complications just at present, we shall speak of CO_2 percentage and not of CO_2 pressure throughout this volume. Needless to say that our present discussions will not be vitiated because of this inaccuracy.

the left has two. (*Vide* Fig. I). The finest subdivisions of bronchial tubes are called *bronchioles.* These bronchioles or the bigger bronchial tubes from which they shoot off, have no alveoli in their walls, and as such they allow no gaseous exchange across their walls. But when these ordinary bronchioles subdivide themselves further, we get bronchioles with alveoli developed in their walls. These bronchioles of the latter type are called *respiratory bronchioles.* (*Vide* Fig. II). In this diagram three respiratory bronchioles have been shown, one of which has developed into three lobules and several ultimate lobules. Before the inspired air reaches the air-cells clustering round the ultimate lobules, it has to pass not only through the respiratory bronchioles, but also through three successive passages or distributing chambers called *alveolar ducts, atria* and *air-sacs.* Like the respiratory bronchioles the alveolar ducts and atria also have their walls covered with air-cells. But the real crowding of air-cells is to be found roundabout the air-sacs. Hence even when air-cells are to be found all along the walls of the air passages and their subdivisions stretching right from the beginning of the respiratory bronchioles up to the air-sacs, by far the greater part of the alveoli are situated roundabout the air-sacs.

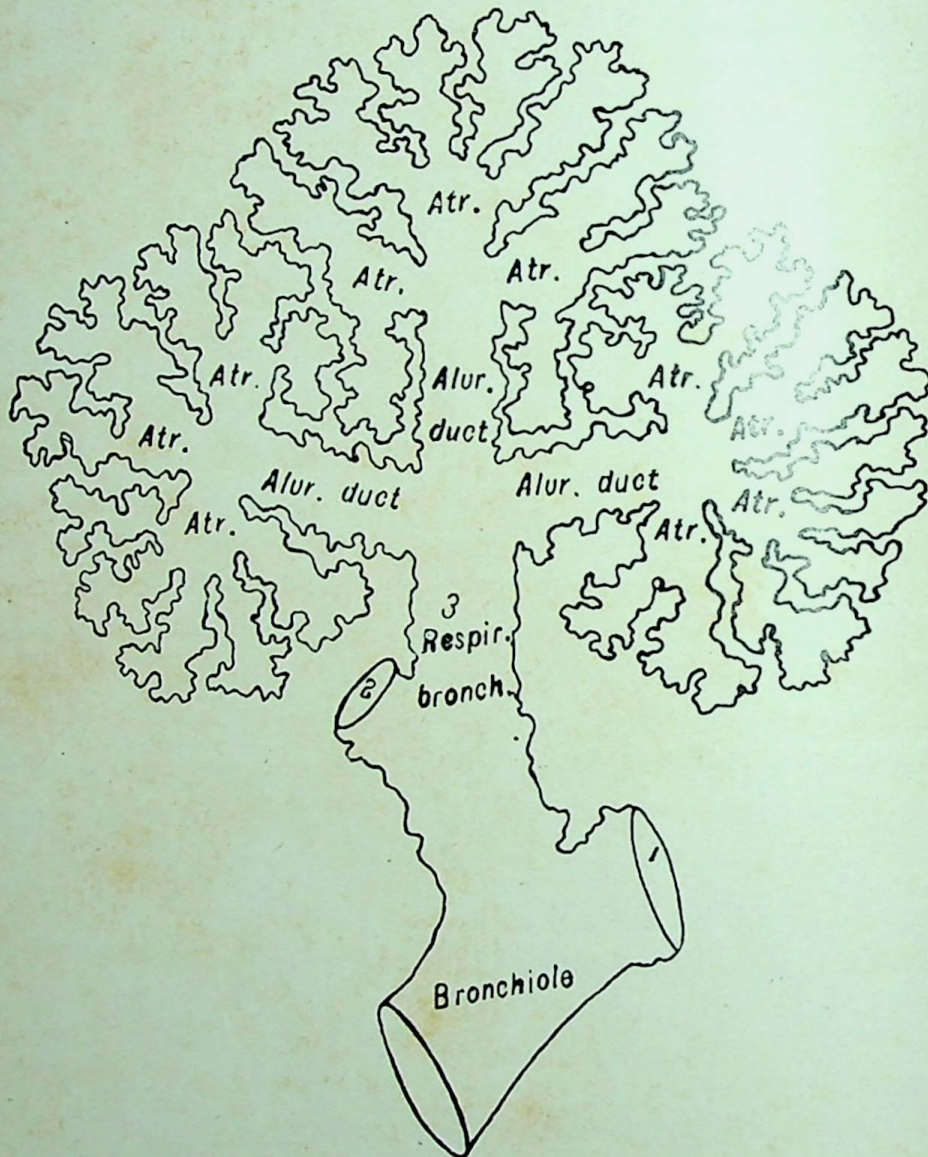
We shall now turn to the physiological description.

The anatomical description given above will show that the respiratory bronchioles, alveolar ducts and atria serve as a passage for the inspired air as it flows to the air-sacs. But besides serving as a passage, these organs perform another function. We have seen that the walls of these parts are lined with air-cells. Now when fresh air passes through these organs, the air-cells in their walls allow gaseous exchange across them and thus partly carry on the work of respiration.[1] Hence the respiratory bronchioles, the alveolar ducts, and the

1 The function of respiration is to remove CO_2 from the blood and to lend it fresh O_2 from the inspired air.

Fig. I

The Thorax Exposed.

(Showing arrangement of the Lobes in the two Lungs)

Fig. II

Line Drawing Showing Arrangement of Three Lung Lobules, with their Bronchiole, Respiratory Bronchioles (Nos. 1, 2 & 3), Alveolar Ducts, Atria and Air-Sacs.

[Reproduced from J. S. Haldane's *Respiration*]

atria serve a double purpose. They serve as passages for the inspired air and serve as respiratory organs also. The air-sacs stand on a different footing. They serve only as respiratory organs, because they are the ultimate chambers in which the inspired air is held, its further progress being blocked up there.

According to J. S. Haldane and Priestley who are considered to be leading authorities on the problems of alveolar air, the air-sac air is the alveolar air, and it is the CO_2 percentage[1] in this alveolar air that regulates the respiratory activity of human beings.

Having definitely ascertained the meaning of the term alveolar air, we shall now proceed to see how this air is collected. For understanding this process of collection we have to notice some more features of the respiratory apparatus and the nature of the expired air.

We know by this time that the air-cells which are really responsible for the respiratory function of gaseous exchange, start making their appearance only with the respiratory bronchioles, these cells being entirely absent from the upper air passages. That means the inspired fresh air is left in tact, that is, it is neither deprived of any of its oxygen nor is loaded with any of the CO_2 from the blood, till it reaches the respiratory bronchioles through the nose, the pharynx, the larynx, the trachea and the bronchial tubes successively. Nor is the inhaled fresh air seriously affected by the respiratory process of gaseous exchange, even when it enters the respiratory bronchioles. There only a small portion of it takes part in respiration and the main portion passes on to the air-sacs where alone the respiratory process is mainly completed. Thus we see that during inspiration some space in the respiratory passage remains occupied by fresh air which takes no part in the process of respiration by way of gaseous exchange. As

1 *Vide* foot-note on p. 43.

this space is useless for the proper respiratory function, it is called the *dead space* by the physiologists.

Whether this dead space occupies a fixed measure of area in the respiratory passage of every individual, and also whether the measure of the dead space which prevents O_2 absorption is the same as or different from the measure which prevents CO_2 elimination, are questions that need not detain us here. We have introduced the subject of dead space here simply because we have to make frequent references to the dead space in explaining the process of alveolar air collection.[1]

By now we have clearly grasped the following facts. (*i*) Alveolar air is the air held in the air-sacs. (*ii*) Between the air-sacs and the nose lie air passages which are partly occupied by the dead space and partly by the active space. (*iii*) At the end of inhalation the air in the dead space is still fresh, uninfluenced by the process of respiration, whereas the air in the active space is changed because of the gaseous exchange. (*iv*) Starting from the air-sacs we first have to go through the active space and then through the dead space before we come to the anterior openings of the nose. Now if we propose collecting *air from the air-sacs* by the process of expiration, it is evident that the fresh air from the dead space must be first driven out, so that the air from the air-sacs may not be mixed up with the pure air, thus affecting the composition of the alveolar air that would come out of the air-sacs. Haldane is of opinion that at the end of normal expiration air from the dead space is *almost entirely* thrown out, so that the forced expiration that would follow would give us practically the air of alveolar composition. He further holds that if we want to have an absolutely reliable alveolar air, we must drive out some additional 300 c.c. of expired air at the end of nor-

1 According to Haldane there is no absolute measure of dead space for any individual. He also holds that the measure of dead space in relation to CO_2 elimination, may differ from its measure in relation to O_2 absorption.

mal exhalation or some 800 c.c. after normal inhalation. In the case of deep breathing, a larger quantity of expired air will have to be sent out, before we can get the alveolar air from the air-sacs. The reliable alveolar air thus obtained may be collected in a vacuous bladder or india-rubber bag for the purposes of laboratory work.

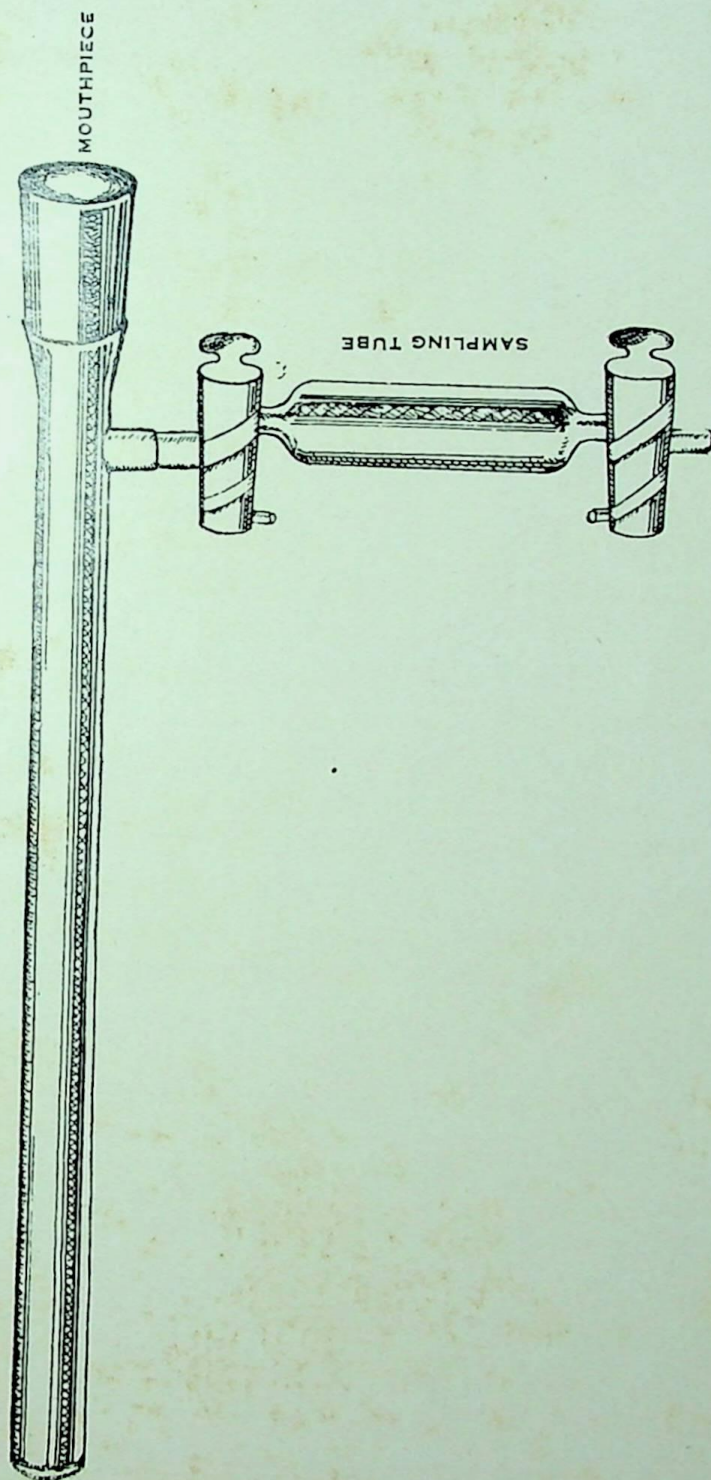
Here we wish to draw the attention of our readers to the fact that the alveolar air thus collected does not give us *all the alveolar air that is expired in one breath.* The reason is this. Before we start collecting the alveolar air, 800 c.c. of expired air are allowed to escape. This quantity of expired air contains a good amount of CO_2 which shows that this part of the expired air is a mixture of the air from the dead space and air from the air-cells, some of which, indeed, belong to the respiratory bronchioles etc., but most of which belong to the air-sacs. It is, therefore, very likely that that part of the expired air which is excluded from our collection, should contain air from the air-sacs or the alveolar air. As we are, however, concerned with the qualitative side of the alveolar air in this note, we shall not further discuss the question of its quantity here; but turn to the problem of getting a reliable sample of alveolar air for its qualitative analysis or more precisely to the problem of finding out the CO_2 percentage present in it.

Our readers must have known by this time that in the process of exhalation the alveolar air, coming as it does from the deepest parts of the lungs, that is, the air-sacs, forms the last part of the expired air. If this last part could be collected, it would give the most reliable sample of the alveolar air. The method introduced by Haldane and Priestley for getting such a reliable sample of the alveolar air, has been tersely described by W. D. Halliburton in his *Handbook of Physiology*. The following relevant paragraph is quoted from the same.

"Haldane and Priestley introduced a simple method of collecting alveolar air which has the advantage of being applicable to man. A piece of rubber tubing is taken about 1 inch in diameter and about 4 feet long. A mouthpiece is fitted into one end. About 2 inches from the mouthpiece a small hole is made into which is inserted the tube of a gas-receiver, or sampling tube, as in the figure (fig. 241[1]). The gas-receiver is fitted at the upper end with a three-way tap, and the lower end is also closed by a tap. Before it is used, the gas-receiver is filled with mercury. The subject of the experiment breathes normally through the tube for a time, and then, at the end of a normal inspiration, he expires quickly and very deeply through the mouthpiece and instantly closes it with his tongue. The lower tap of the receiver is then turned, and as the mercury runs out, a sample of the air takes its place and fills the receiver; this sample is then analyzed. A second experiment is then done, in which the subject expires deeply at the end of a normal expiration, and another sample obtained. The mean result of the two analyses represents the (average?) composition of the alveolar air. Since the gaseous interchange between the blood and the alveolar air is going on continuously, it is evident that at the end of inspiration there will be a maximum percentage of oxygen, and a minimum percentage of carbonic acid; the converse obtains at the end of expiration. These observers proved by other considerations into which it is unnecessary to go, that the air obtained was really the *alveolar air* (italics ours) unmixed with any of the air of the 'dead space' of the respiratory passages."

As will be clear from this quotation, the sample of alveolar air obtained at the end of inspiration differs in quality from the sample obtained at the end of expiration, the former sample containing a smaller percentage of CO_2 than the latter. In a number of experiments carried out upon himself, Haldane found the inspiratory sample to contain on an average 5·54 per cent. of CO_2 and expiratory sample to contain 5·72 of

1 Reproduced here as Fig. III.

Fig. III

Apparatus for Obtaining Alveolar Air.

[Reproduced from W. D. Halliburton's *Handbook of Physiology*]

that gas. Similar experiments done with Priestley as the subject, gave 6·17 and 6·39 as the CO_2 percentages in the respective samples. Working out the averages from the two samples, inspiratory and expiratory, we find that the mean CO_2 percentage in the alveolar air in the case of Haldane is 5·63; whereas the same in the case of Priestley is 6·28. When we talk of CO_2 percentage in the alveolar air, we generally refer to this mean percentage unless specified otherwise.

Experiments referred to in the last paragraph were performed while the subjects were at rest and their respiration was normal. Similar experiments were performed by Haldane and Priestley with subjects under different working conditions, with different rates of respiration and also with respirations of different depths.

The two scientists under reference, have based various conclusions upon these researches of theirs. We shall take into account only four of them as we are at present concerned only with these and not with others.

1 In normal respiration, the expired air which is exhaled after driving out 800 c.c. at the end of inspiration, constitutes reliable alveolar air.

2 When two different samples of alveolar air are taken, one inspiratory and the other expiratory, the expiratory sample will generally contain a larger percentage of CO_2 than the inspiratory sample.

3 The composition of the alveolar air is the same. Hence the deepest parts of the alveolar air will contain the same percentage of CO_2 as the middle parts.

4 Under normal conditions the breathing in man is regulated by the alveolar CO_2 percentage[1]; and a very slight increase or diminution in the alveolar CO_2 percentage suffices to cause a very great increase or diminution in breathing.[2]

1 *Vide* foot-note on p. 43.

2 This conclusion is so important from the Pranayamic point of view, that we promise our readers a very detailed consideration of it later on.

PART II

In the first part of this note we have summed up the research work of some leading physiologists regarding the question of alveolar air. In this part we wish to compare that research work with the work which we have been doing; and if there be any difference in their results and our results, to discuss the cause of that difference. At this stage of our research work we have absolutely no desire to jump to any final conclusions and we warn our readers not to wrongly interpret our statements. What we want to do at present is to clearly bring out the difference between their methods of investigation and ours and to set forth subsequent difference in results. We also wish *to put forth some suggestions* regarding the comparative merits of the two methods, and also the relative accuracy of the results. We sincerely request the physiological scientists to subject our suggestions to a critical examination and to favour us with their reasoned criticisms. Nothing will please us more than to publish such criticisms in the pages of this journal.

To begin with we shall take into consideration the method of sampling the alveolar air. The simple method of sampling the alveolar air which was devised by Haldane and Priestley, and which has found favour with physiologists has been described in the words of Halliburton on p. 48. In this method a hose or rubber pipe four feet in length and one inch in diameter, is used for collecting the alveolar air. With a view to secure a sample of the last part, a sampling tube is attached to this pipe near that end of it, through which the subject blows. This sampling tube is at first filled with mercury. As soon as the alveolar air is collected in the hose-pipe, the mercury from the sampling tube is allowed to flow out, thus creating a vacuum in the tube and drawing in the alveolar air from the pipe to take its place.

Here the following points require examination.

(*i*) Whether the successive portions of the expired air occupy successive parts of the hosepipe, so that the deepest portion may be surely found nearest to the mouthpiece ;

(*ii*) Whether by the time the process of securing a sample is completed, there is a chance of the different portions of the alveolar air contained in the pipe being mixed up, so that the whole quantity might approach approximation in composition ;

(*iii*) Whether the reverse current of air that would be set up in the pipe because of the vacuum in the sampling tube, would not help this approximation in composition.

Taking up the first point, we have to know whether the successive portions of the expired air occupy successive parts of the hosepipe, so that the deepest portion may be surely found nearest to the mouthpiece. What we mean is this. Supposing the capacity of the hosepipe to be something like 600 c.c., whether the last 600 c.c. of the expired air would be definitely so distributed in the pipe that the last 200 c.c. would be found in that one-third part of the pipe which is nearest to the mouthpiece, so also whether the middle 200 c.c. would be found in the middle one-third of the pipe and the remaining 200 c.c. would be found in the remaining one-third of the pipe. This should surely have been the case had the current of the expired air moved through the pipe in such a way that each of its successive parts, from the beginning to the end, would push its forerunner bodily ahead. But such a thing never happens when air passes along an air passage. The air current divides itself as it were in two parts—the axial current and the peripheral current, the axial current moving much faster than the peripheral stream. That being a general rule, the expired air blown through the hosepipe can be no excep-

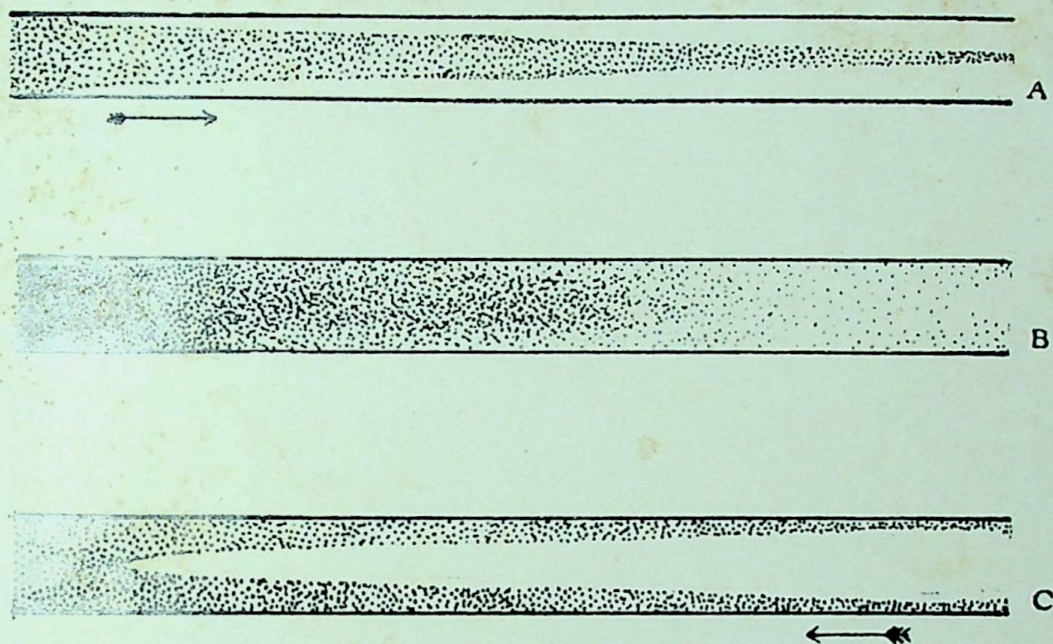
tion to it. The result would be *something like* this. By the time the air of the first 200 c.c. that runs through the axial current comes to occupy the most distal part of the pipe, that portion of these 200 c.c. which runs through peripheral stream will occupy only the middle part of the pipe. There it will naturally come in contact with the axial stream of the middle 200 c.c. Similar situation will occur in the first one-third of the pipe also. The peripheral stream and the axial stream will not belong to the same portion of the expired air.[1] The result will be that there will be a mixing up of the different portions of the expired air and it would be impossible to secure a scrupulously pure sample of a particular part of the alveolar air, whether the sample consists of 200 c.c. or of a larger or a smaller quantity. Under such circumstances it would not be quite accurate to say that the sampling tube would catch up only the last portion of the expired air blown through the hosepipe.[2]

Coming to the second point which we wish to examine, we want to know whether by the time the process of securing a sample is completed, there is a chance of the different portions of the alveolar air contained in the pipe being mixed up, so that the whole quantity might come nearer approxima-

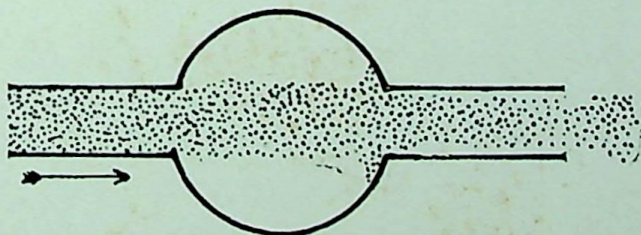
1 We have made our statement too mechanical, only to give our readers a very clear grasp of the subject. The actual situation in the hosepipe will not be so rigidly accurate, because both the axial stream and the peripheral stream will be continuous and will not be travelling at a uniform speed throughout the act of expiration.

2 Our readers will be interested to know that the principle underlying the discussion in this paragraph, namely, the unequal speed of the axial and peripheral currents of air passing through an air passage, has been recognized by Haldane. Here is a quotation taken from his book on *Respiration.*

"It was shown by Yandell Henderson and his coadjutors that when air passes along an air passage the axial stream is much faster than the peripheral stream, and that as a consequence of this the air in the dead space is not pushed out bodily in front of the alveolar air during expiration. Some of the tracheal and bronchial air is at first left behind, and before pure alveolar air issues at the nose or mouth the air passages have to be washed out by three or four times their volume of alveolar air. This is illustrated by figures 9 and 10 (reproduced here as Figs. IV and V), taken from their paper, and drawn from experiments made with smoke."

Fig. IV

(*A*) Shows a "Spike" of Smoke Moving through a Glass Tube.
(*B*) Shows the Condition when the Current is Suddenly Stopped and Mixing Instantaneously Occurs.
(*C*) Shows Clear Air Drawn in.

[Reproduced from J. S. Haldane's *Respiration*]

Fig. V

Shows How a Column of Smoke Crosses a Bulb with Little Mixing or Sweeping out of the Air Within it.

[Reproduced from J. S. Haldane's *Respiration*]

tion in composition. In discussing this point we have to remember that it takes full half a second for collecting the expired air in the hosepipe and it must take much more than this time for a sample to be secured in the sampling tube. That means, the air in the pipe stands there for upwards of a second, before the process of sampling is completed. How will the different gases contained in the expired air held in the pipe, behave during all this time? Will they not become diffused, if not completely at least partially, thus tending to render the whole quantity of air in the pipe approximately of uniform composition? It is to be noted that the phenomena of diffusion occurs very quickly. Our readers can understand this quickness quite easily, if they are told that in a single quick respiration which does not take even half a second, so much of CO_2 is diffused from the blood into the inhaled air and so much O_2 is diffused from the inspired air into the blood. It will thus be seen that in a second's time there will be considerable diffusion of gases in the hosepipe and the original composition of the different parts of the expired air, will be seriously disturbed. Under these circumstances, it is difficult to see how the sampling tube can draw in a reliable sample of the last portion of the alveolar air.

Coming to the third and the last point, we want to find out whether the reverse current of air that would start in the hosepipe on account of the vacuum in the sampling tube, would not help the process of diffusion alluded to in the last paragraph, thus leading to further approximation in composition on the part of the air collected in the hosepipe. Haldane himself gives a caution against taking out too large a sample, because he says[1] that such a sample may draw in some pure air, across a length of four feet through the free end of the hosepipe. A small sample will surely avoid this possibility; but even a small sample will as surely set up a current in the opposite direction, which even if very weak, will not fail

1 "If the sample is too large, some pure air may be drawn in." Foot-note 5, p. 17, *Respiration*—By J. S. Haldane.

to disturb the original composition of the different parts of the air in the hosepipe.

In this way all the three points which we raised in the beginning of this part of our note, do not seem to bear critical examination. The foregoing discussion of these points is sufficient to show that the method devised by Haldane and Priestley for sampling the alveolar air is not calculated to give us a reliable sample of the deepest parts of the expired air. The question as to whether this *possibly defective* method of sampling, has vitiated any of Haldane's theories about respiration, requires further research. At present we shall start investigating only one conclusion[1] of his, namely, the deeper parts of a very deep breath have *exactly the same composition* as the middle parts or in other words, the alveolar air is uniform in its composition.[2] But before we do this we shall briefly refer to the method which we are following in our laboratory for collecting the deeper and the deepest parts of the alveolar air.

Whether in normal or forced respiration, the subject is made to exhale slowly but very deeply, so that the act of exhalation would be completed in seven seconds. During the first five seconds, the subject exhales only as much air as would leave behind 400 to 500 c.c. of supplemental air approximately. During the sixth second the subject exhales about 200 to 250 c.c. through the mouth in a vacuous bladder or india-rubber bag, and during the seventh second he exhales the remaining air in another bag of the same type, both the bags being clipped immediately. Needless to say that the first bag contains deeper parts of the alveolar air and the second bag the deepest parts.[3] Air from both the bags is analyzed in the laboratory according to the standard methods

1 The third of the four conclusions of Haldane mentioned on p. 49.

2 In this number we are concerning ourselves only with the CO_2 percentage in the alveolar air and not with the percentages of all the gases in that air.

3 In the *Scientific Section* of this number while discussing the experiments, the deeper part is designated as the *last but one part*, and the deepest part as the *last part* of the alveolar air.

of gas analysis, and the results are noted down. For the experiments published in the *Scientific Section* of this number, we collected 200 to 250 c.c. in each bag. It is possible[1] to make those collections smaller still and to collect 2, 3 or even 4 successive parts of the deepest expiration, each containing approximately 100 to 150 c.c. of air.

The greatest advantage of this method is to exclude completely the possibility of the diffusion of gases from the different parts of the alveolar air, and the consequent danger of its approximation in composition. Each part is held in an airtight bladder and remains pure till it is analyzed.

It may be pointed out to us here, that the time of seven seconds allotted to the process of expiration, would increase the CO_2 concentration progressively in the successive parts of the expired air. We have dealt with this point in the *Scientific Section* of this number, and have admitted that the actual percentage of CO_2 in the collection of the seventh second, should be taken to be slightly lower than what it is found out to be in analysis, when the composition of this collection is to be compared with that of the sixth second.

Returning to the examination of Haldane's conclusion which we are discussing in this note, let us first examine[2] the CO_2 percentages in the last and the last but one parts of the alveolar air as they were found in our analysis without taking into consideration the point raised in the last paragraph. Tables XI, XII and XV clearly show that *out of 18 comparisons made, in 16 comparisons the CO_2 percentage was found higher in the last but one part than in the last part.* When we lower down the CO_2 percentage in the last part because of the delay in its collection, we find the difference between the two

1 We must at once admit that the method we are following in our laboratory requires subjects who are trained in regulating their breaths. As, however, our investigations lie in the field of Yoga and in the methods of regulating respiration, we would always require trained subjects.

2 For detailed examination see the *Scientific Section* of this number.

CO_2 percentages still more striking. Even in Table X two subjects out of six show a higher CO_2 percentage in the last but one part of the alveolar air than in its last part.

In the face of these results can we reasonably say that the deeper parts of a very deep breath have *exactly the same composition* as the middle parts ? Our reason would certainly insist upon further investigations being made before we can accept this general conclusion of Haldane.

Nor can it be seriously maintained that the differences we noted in the middle and deeper parts of the alveolar air so far as the CO_2 percentages in them were concerned, should not be considered as of much consequence, when Haldane himself asserts that 0·01 per cent. more or less of CO_2 in the alveolar air, is sufficient to affect respiration.[1]

Thus far we have discussed the third of the four conclusions of Haldane mentioned at the end of the first part of this note. A passing reference has also been made to his second conclusion in the *Semi-Scientific Section* of this number.

The research work published in this number is not intended to establish any theory or to formulate any general proposition about CO_2 percentages in the different parts of the alveolar air. Our present purpose is to examine the present day physiological notions of respiration. As Haldane, a great authority on the subject of respiration, attaches so much importance to the CO_2 percentage in the alveolar air in propounding his theories, we thought it best first to concentrate on that point only. Further investigations will be published in the succeeding numbers of this journal. It will, however, take a very very long time for us to establish finally any theory of our own, even if we are required to establish one at all.

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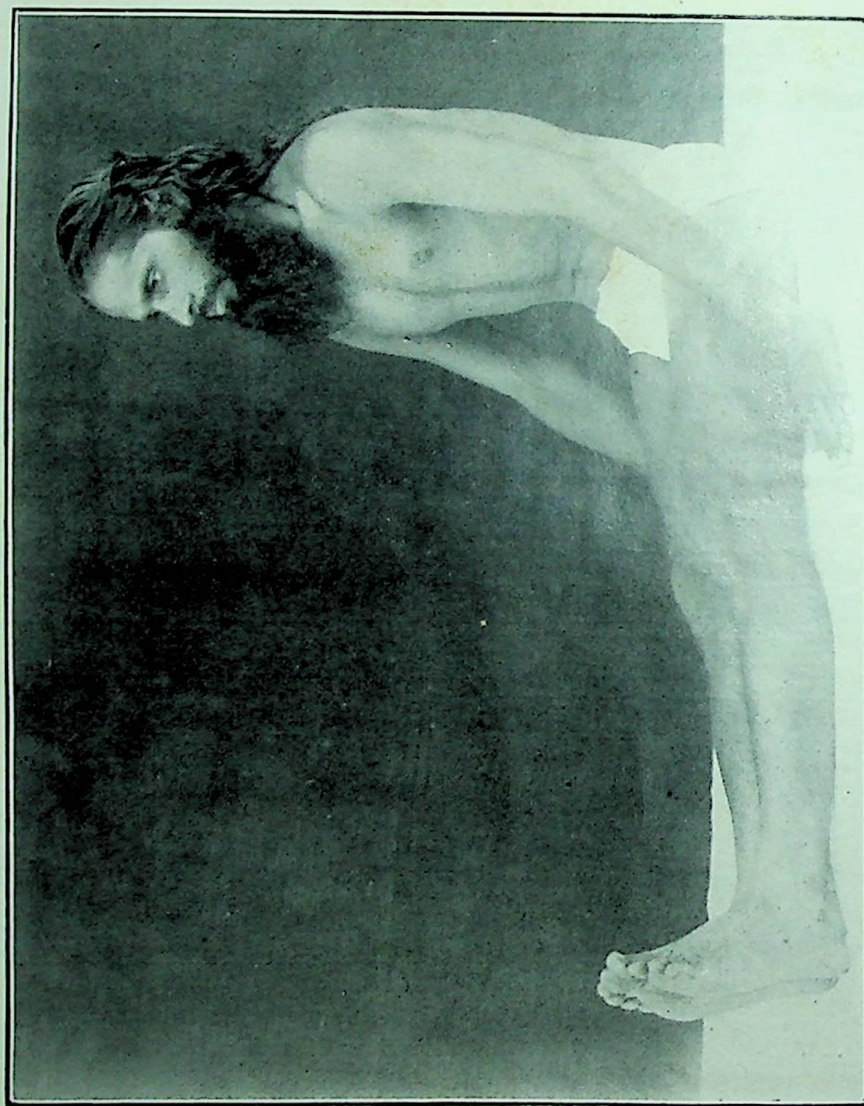
1 The astounding sensitiveness of the respiratory centre to CO_2 is thus clearly established in both an upward and a downward direction. A mean increase or diminution of 0·01 per cent. in the alveolar CO_2 will evidently produce an increase or diminution of 5 per cent. in the alveolar ventilation, or of about 400 c.c. per minute in the lung ventilation.

The Popular Section

N. B.—Instruction in Yogic culture higher as well as lower will be given gratis at the Âśrama to everyone that earnestly seeks it.

Fig. VI

Preparing for Mahâ-Mudrâ.

MAHÂ-MUDRÂ

THE NAME :—

The compound Mahâ-Mudrâ consists of two words: Mahat (changed to Mahâ) and Mudrâ. In Saṅskṛita Mahat means *great, of great physical and spiritual value.* Mudrâ[1] means *a particular arrangement of contracted muscles.* This Mudrâ is called Mahâ-Mudrâ because of its great efficacy in awakening the spiritual force of Kuṇḍalinî.

THE TECHNIQUE :—

The technique of Mahâ-Mudrâ may be described in four parts, each part corresponding to some exercise that we have already studied in the pages of this journal. Thus the first part corresponds to a part of Siddhâsana, the second to a part of Paśchimatâna, the third to Ujjâyî and the fourth to a simultaneous practice of the three Bandhas— Mûla, Uḍḍiyâna and Jâlandhara. We shall study these four parts of the technique one by one.

The first part of Mahâ-Mudrâ corresponds to that part of Siddhâsana which requires one of the heels to be pressed against the perineum. This may be done as follows. The student first takes his seat with his legs fully stretched out side by side. (*Vide* Fig. VI). He then bends his left leg in the knee-joint and folding it

1 Our readers will see that we have assigned to Mudrâ the same meaning that we had given to Bandha. In fact in Yogic literature the words Bandha and Mudrâ are sometimes used as synonyms. Thus Uḍḍiyâna, Mûla etc., are designated both as Bandhas and Mudrâs. It may be noted, however, that the word Mudrâ has a much wider application than the word Bandha. It should not, however, be inferred that a particular class of Mudrâs is called Bandha. For instance Jihvâ-Bandha is not a Mudrâ. Thus it is difficult either to make any exact distinction between the two words or to take Mudrâ as a generic and Bandha as a specific term. The meaning suggested by us for the words Mudrâ and Bandha, is admittedly very vague.

upon itself, sets its heel tightly against the perineum with the help of his right hand. (*Vide* Fig. VII). In order to get the perineum clear for this purpose, he has first to hold up his genitals with the left hand, for the right hand is engaged in setting the heel in its proper place. Care should be taken to see that no part of the scrotum is caught up between the heel and the perineum. The sole of the left foot should be closely in touch with the right thigh. No attempt should be made to sit on the heel. That is a wrong procedure, because pressure is to be exerted on the perineum and not on the anus. The adjusted heel must feel the hard touch of the bones on the two sides of the perineum. After the left leg is given its proper position, the genitals should be allowed to lie wherever they be.[1] No further attention to them is necessary. This completes the first part of the technique.

The second part of the technique corresponds to a part of Paśchimatâna, although this correspondence is not so exact as that between the first part and Siddhâsana. Broadly speaking the second part of the Mahâ-Mudrâ technique consists of catching the extended leg in the foot. We shall see how this is done in detail. After adjusting the left heel, the student prepares a finger-lock by interweaving his right fingers with the left. This finger-lock can be clearly seen in Fig. VIII. Then bending over his extended leg, he catches hold of the foot just below the toes,[2] and gives such a gentle but steady pull

1 This particular piece of advice is intended for spiritual culturists only. They are expected to practise Mahâ-Mudrâ without any covering even for their genitals. If any covering is used at all, it would be so thin and so loosely worn that it would not keep the genitals in position while practising Mahâ-Mudrâ. Physical culturists could continue to wear their moderately tight *Langot* put on for other exercises.

2 Whether the foot is caught in the finger-lock below the toes as shown in Figs. IX and XI or covering the toes as shown in Fig. X is somewhat immaterial, if the pull is felt just below the toes.

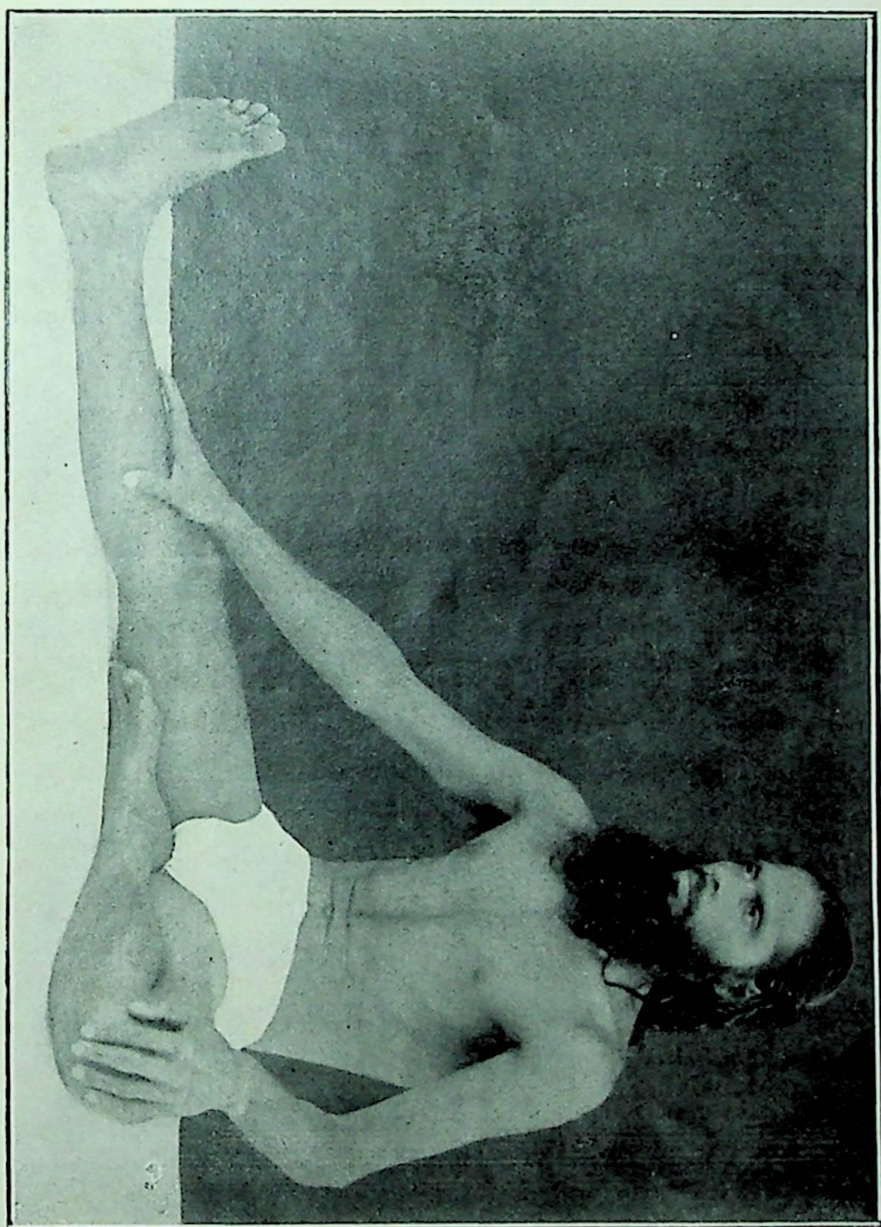
Fig. VII

The Left Heel Set against the Perineum.

Fig. VIII

The Finger-Lock.

to it, that the knee-joint is fully straightened, and the hamstring and other posterior muscles of the leg are completely stretched. (*Vide* Fig. IX). Care should be taken to see that the knee does not bend, otherwise the pull in the lumbosacral region would be weakened and the results of the Mudrâ would suffer consequently.

It is true that the practice of Mahâ-Mudrâ is advised generally to advanced students of Yoga. It is not, however, impossible for this exercise to be prescribed to a beginner, of course with the necessary modifications[1] in its technique. In such cases the hints given to physical culturists under Paśchimatâna, will be of great value to the students of this Mudrâ. We reproduce them here *in extenso* with a few verbal changes.

In the case of nearly every beginner, the hamstring muscles— muscles which when contracted enable us to bend our knee and which are situated at the back of it — do not possess the elasticity necessary for this Mudrâ. The result is that the knee is raised, when one tries to bend over his thigh. By a little practice, however, young and well-built persons can soon make the hamstring muscles sufficiently elastic, so that there will be little trouble in securing the desired bent even without raising the knee.

But people who are advanced in age, or are prematurely old, or have stiffened their muscles by over-exercise, stand on a different footing. They experience an amount of difficulty in bending their trunk effectively while maintaining a straight knee. Their spine is so stiff, that they cannot reach their toes even with their fingers.

1 We shall study some of these modifications in the *General Hints* given at the end of this article.

There is, however, absolutely no reason for these people to become impatient over the matter. They should proceed into the practice of this Mudrâ slowly but steadily. Instead of trying to catch hold of their foot in the finger-lock, they should seize their leg, either in the ankle or even higher up nearer the knee. Without experiencing much discomfort, the trunk should be bent forward as far as possible, but the knee should always be kept stiff. This little bent maintained for a time, will invariably make further flexing possible. As usual jerks, whether violent or mild, should be studiously avoided. In a few days, the spine will show signs of improved elasticity, and the hamstring muscles will be better able to bear the necessary strain. When the hands could be stretched comfortably a little beyond the extended foot, the student should try to catch it in the finger-lock and to stretch by degrees the whole system of the posterior muscles. Elasticity will develop day by day, ultimately making the practice not only possible but even comfortable. Patience and perseverance must overcome every difficulty. Regularity is, indeed, essential; but we also advise punctuality. These two will enable almost every Yogic culturist to perform any exercise within a reasonably short period.

When the student has adjusted his heel and caught his foot in the finger-lock, the first two parts of the technique will have been completed and he will be ready to go through the third part of it. As stated in the beginning this third part corresponds to Ujjâyî.[1] The student simply inhales deeply through both the nostrils as in Ujjâyî, paying special attention to the control of the

1 Inhalation and exhalation of the Sûryabhedana type is also available in this Mudrâ. Pûraka and Rechaka whether they are as in Ujjâyî or as in Sûryabhedana must be practised through both the nostrils in this exercise.

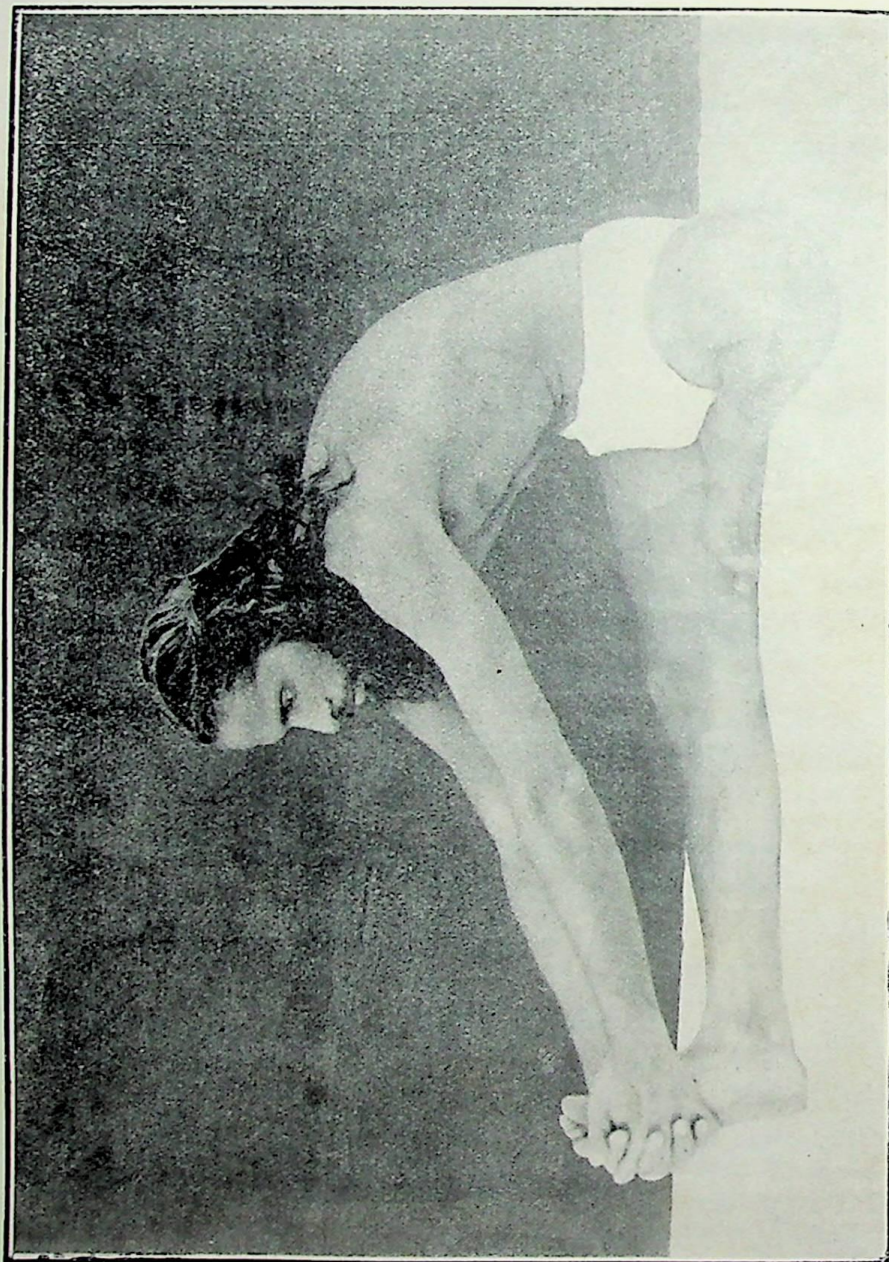
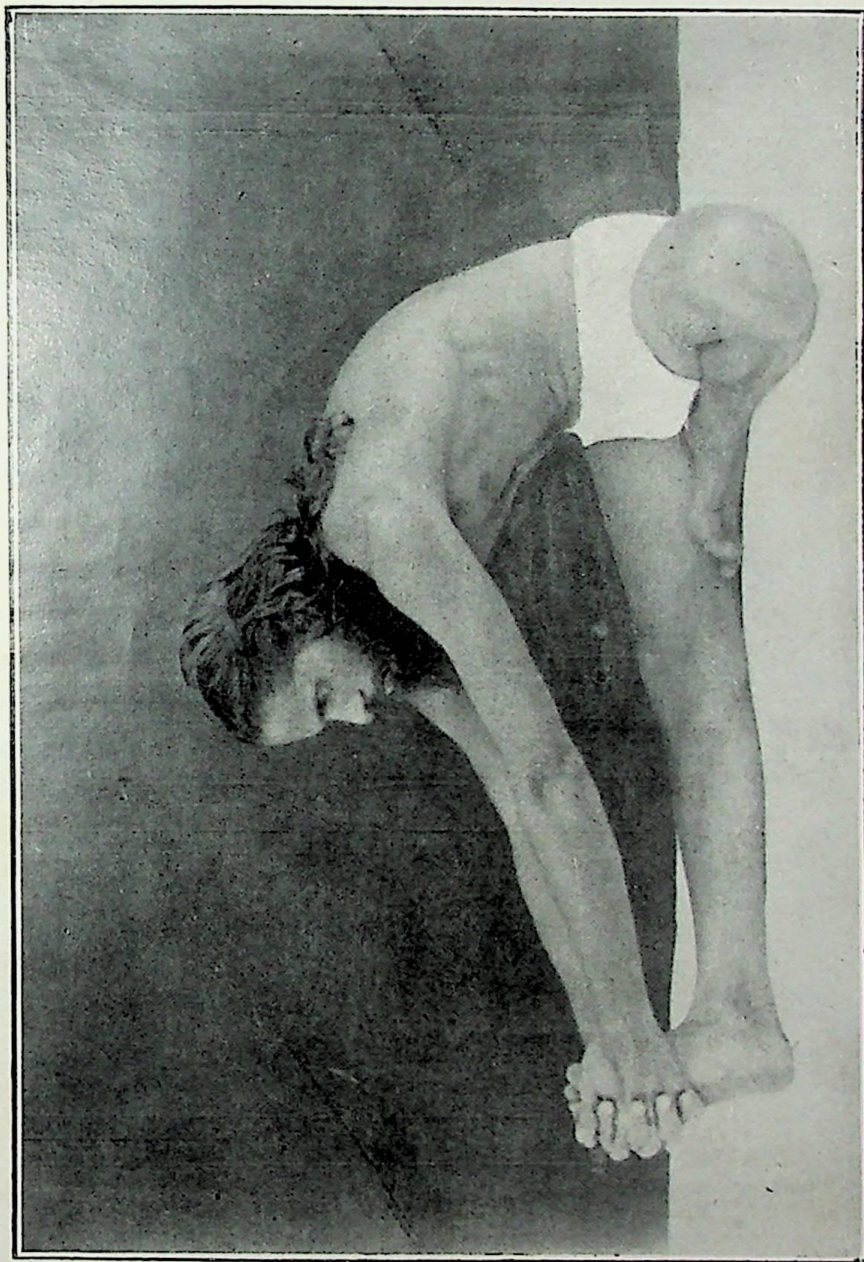
Fig. IX

Catching Hold of the Extended Leg.

Fig. X

Abdomen at the End of Inhalation in Mahâ-Mudrâ.

abdominal muscles. When inhalation is completed, the glottis is closed for the practice of Kumbhaka.

It may be noted here, that the front abdominal muscles become considerably contracted, when the student bends over his extended leg. This contraction becomes the more vigorous when the student catches hold of his foot and gives a steady pull to it. So when inhalation is started in the third part of the technique, the possibility of the bulging out of the abdomen is minimized. Even then the student should be on his guard and should not allow the abdominal muscles to relax their activity, although a little protrusion is unavoidable, because of the vigorous descent of the diaphragm, driving the abdominal viscera before it during inhalation. A comparison between Figs. IX and X will bring out the contrast between the normal and the inspiratory appearances of the abdomen in this exercise.

With the closure of the glottis after inhalation the fourth part of the technique begins. This part consists of a simultaneous practice of the three Bandhas—Mûla, Uḍḍiyâna, and Jâlandhara, while Kumbhaka is being maintained. These Bandhas have already been described in the pages of this journal as they are practised separately. Mula-Bandha[1] consists of a vigorous anal contraction, one of the heels pressing the perineum at the same time. Jâlandhara-Bandha[2] requires the chin closely to be pressed against the chest either in the jugular notch or four fingers below it. Uḍḍiyâna[3] demands mock inhalation to be maintained with the glottis

1 First described in *Vol. II* on p. 224.

2 First described in *Vol. II* on p. 223.

3 First described in *Vol. I* on p. 9-10, and again in a far better form in *Vol. IV* on pp. 318-19.

closed at the end of deepest expiration by raising the ribs and consequently[1] the diaphragm.

Now the simultaneous practice of these Bandhas too does not require much additional explanation, except in the case of Uḍḍiyâna. Setting of the heel against the perineum already finishes a part of Mûla-Bandha technique. So when the anus is contracted during Kumbhaka, Mûla-Bandha as required in Mahâ-Mudrâ is rightly performed. In our descriptions of Ujjâyî and Bhastrikâ, we have seen how to practise Jâlandhara-Bandha while Kumbhaka is being maintained. So Jâlandhara-Bandha does not require any special instructions even when it is to be performed as a part of the Mahâ-Mudrâ technique. The case of Uḍḍiyâna is, however, different. Up to now we have studied this Bandha as it is practised while exhalation is being maintained. We do not yet know[2] anything about the technique of this Bandha as it is practised while inhalation is being maintained, that is, during Kumbhaka. We have, therefore, to study this second type of Uḍḍiyâna in some detail here.

A reference to p. 318 of the fourth volume will show that the ordinary type of Uḍḍiyâna is secured principally by three actions: the fixing up of the neck and the shoulders, the vigorous mock inhalation preceded by the deepest possible exhalation, and the simultaneous relaxation of the contracted front abdominal muscles. Now the new type of Uḍḍiyâna which we are studying as a part of Mahâ-Mudrâ, requires all these actions for its performance, the only difference being observed in the case of the condition of the lungs. In the ordinary

1 This relation between the rising ribs and the rising diaphragm has been very lucidly explained in *Vol. III* on pp. 220-22.

2 A passing reference to this type of Uḍḍiyâna has, however, been made in *Vol. IV* on p. 40, so also once or twice again in the pages of this journal.

Uḍḍiyâna mock inhalation is attempted while the lungs are in the position of exhalation, while in this Uḍḍiyâna mock inhalation is attempted while the lungs are already in the position of inhalation. We shall now briefly study all the three actions as they are performed in this particular Uḍḍiyâna.

Catching hold of the foot in the finger-lock and steadily tugging at it, fixes up the shoulders and the neck. When these parts are fixed up, they afford a firm support from which the muscles of the neck and the intercostals act, thus enabling the student to raise his ribs. Here it is to be remembered that the chest is already in the inhalation position, owing to previous inspiration necessary for Kumbhaka. That means the ribs are already elevated. This elevation of the ribs brought about by merely the inspiratory act, is not so complete as can be obtained by fixing up the neck and the shoulders with a steady support of the hands. Hence the possibility of raising the ribs still further even when they are already raised. This further elevation of the ribs, would lead to further opening out of the thorax, and if the glottis is open and if the student so wishes, additional air may be inspired. But the purpose of the additional elevation of the ribs, is not to secure further inhalation. Thereby the student wishes to lower down the intra-pulmonary pressure. Hence the glottis is kept closed and no air is allowed to get in. It is obvious that the further elevation of the ribs being very small, the consequent fall in the intra-pulmonary pressure also is very small.

When this much is done, the student is ready to attempt the third step in the technique of Uḍḍiyâna which requires relaxation of the front abdominal mus-

cles. In the ordinary Uḍḍiyâna this relaxation follows a complete contraction of the said muscles and is thorough. In the present Uḍḍiyâna also the relaxation is to follow complete contraction; but owing to many anatomical and physiological considerations,[1] remains incomplete. The result is that while this type of Uḍḍiyâna is being maintained, the abdominal muscles stand contracted much more vigorously than they are when Kumbhaka is maintained with Mûla and Jâlandhara Bandhas only. Consequently the intra-abdominal and intra-pulmonic pressures are raised because of this Uḍḍiyâna and not lowered as in the case of the ordinary Uḍḍiyâna.[2]

Fig. XI represents complete Mahâ-Mudrâ with the three Bandhas. Our readers may be tempted to compare Figs. IX, X and XI for understanding the appearance which the abdomen would assume, when it is in a normal condition as in Fig. IX, or in an inspiratory[3] condition as in Fig. X or in the condition of an inspiratory[4] Uḍḍiyâna as in Fig. XI. But the abdominal appearance in these three figures differs so slightly that the readers are likely to be disappointed. We are, therefore, giving two additional figures (Figs. XII and XIII), to illustrate the abdominal appearance in the expiratory and the inspiratory Uḍḍiyâna respectively. Side views have been chosen to make the contrast easily appreciable.

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1 These considerations are too complicated to be easily grasped by the generality of our readers at this stage.

2 In this connection experiments concerning Pressure Changes in Prâṇâyâma published in the first number of volume four, will be found interesting. We draw our readers' attention especially to Experiments VIII, IX and X and the table given on pp. 42 and 43 of that number.

3 The condition of the chest and the abdomen at the end of inspiration is called inspiratory condition.

4 Uḍḍiyâna performed at the end of expiration as is done in the case of ordinary Uḍḍiyâna may be called expiratory Uḍḍiyâna, whereas Uḍḍiyâna practised at the end of inspiration as required in Mahâ-Mudrâ may be called inspiratory Uḍḍiyâna.

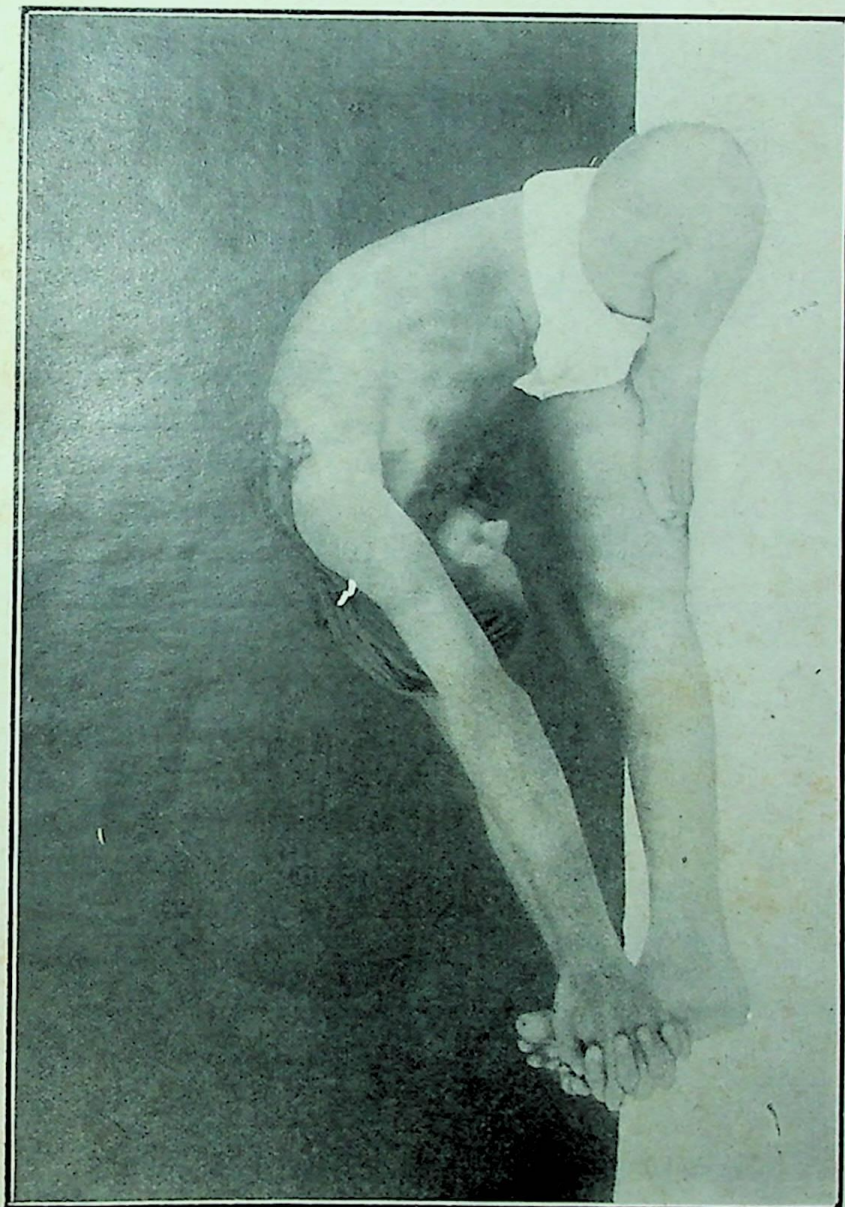



Fig. XI

Complete Mahâ-Mudrâ with the Three Bandhas.

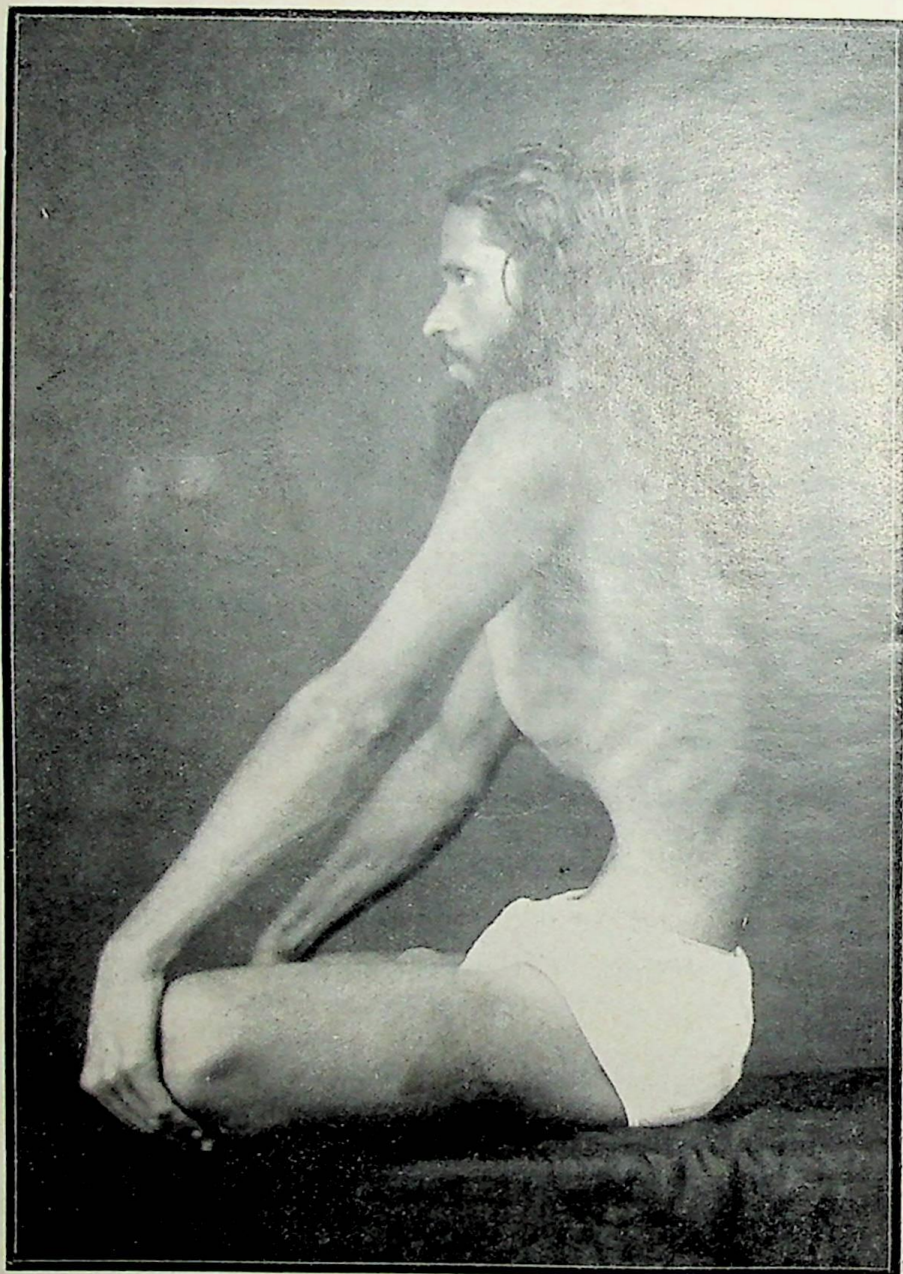
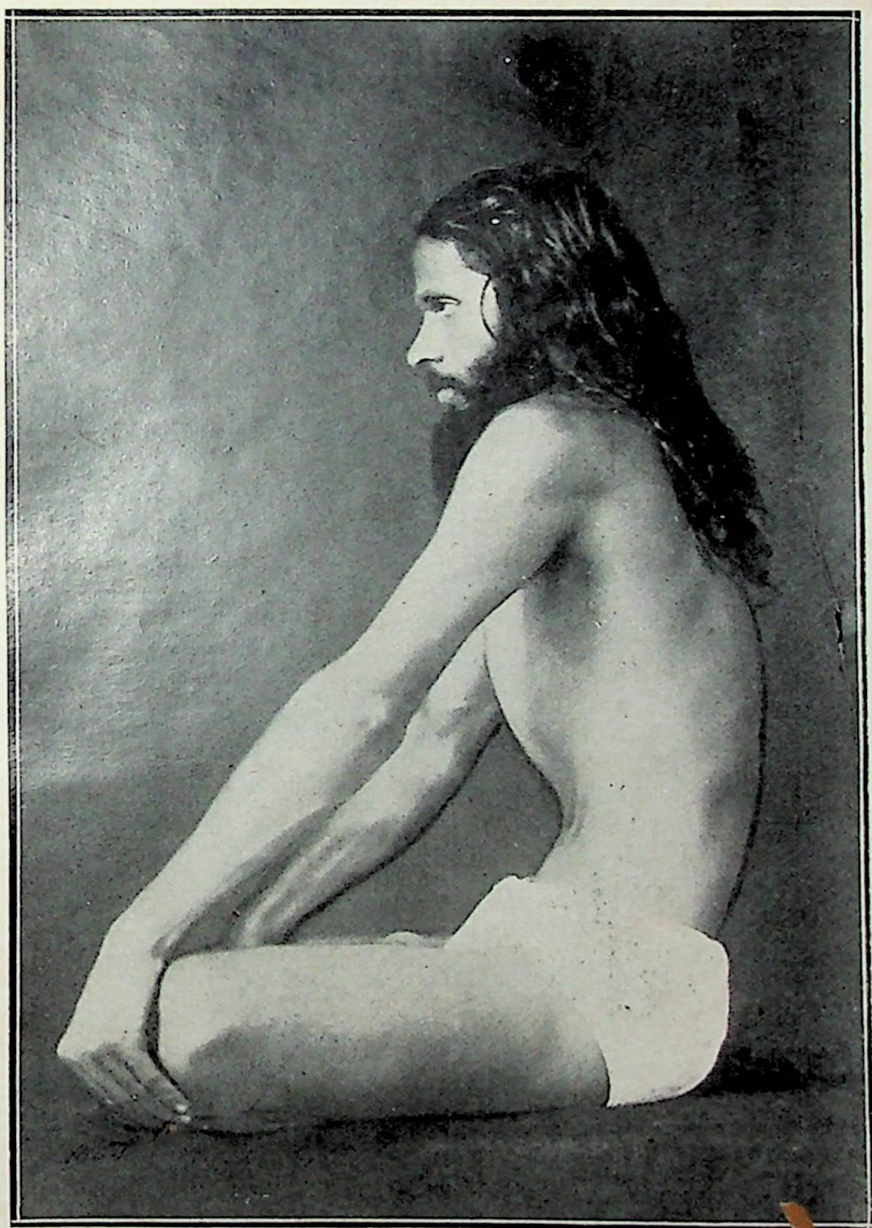
Fig. XII

Expiratory Uḍḍiyâna.

Fig. XIII

Inspiratory Uḍḍiyâna.

With the practice of Uḍḍiyâna the technique of Mahâ-Mudrâ is completed. Thus we see that this Mudrâ requires four things to be done. First, pressing the heel against the perineum; second, catching in the finger-lock the foot of the extended leg; third, maintaining Kumbhaka; and fourth, the simultaneous practice of the three Bandhas. The whole technique of Mahâ-Mudrâ would be expressed very briefly and yet very clearly, if we say that it is Prâṇâyâma practised with the three Bandhas in the pose Paśchimatâna combined with Siddhâsana.

This equation of Mahâ-Mudrâ with Prâṇâyâma supplies us with a unit with which we can determine the measure of the Mudrâ. It is evident that the Mudrâ lasts so long as Kumbhaka is maintained. That means the measure of Kumbhaka is the measure of the Mudrâ. If a student is able to maintain Kumbhaka, say 30″, the proper measure for him for practising Mahâ-Mudrâ would be 30″ also. Students should, however, take special notice of the following fact. The practice of Kumbhaka in a meditative pose and without the Bandhas, is much simpler and far less strenuous than the practice of Kumbhaka in Paśchimatâna with the three Bandhas, as is required in this exercise of Mahâ-Mudrâ. Hence it is desirable that the Kumbhaka measure in Mahâ-Mudrâ is made much shorter than the measure of ordinary Kumbhaka. Thus a student who can comfortably maintain the ordinary Kumbhaka for 30″, would be well advised to maintain the Mahâ-Mudrâ Kumbhaka only for 15 seconds. The end of Kumbhaka marks the point where retracing the steps taken in the performance of Mahâ-Mudrâ, begins.

In retracing the steps of Mahâ-Mudrâ, the student first relaxes the two Bandhas, Uḍḍiyâna and Mûla al-

most simultaneously, the relaxation of Jâlandhara following immediately thereafter. He then straightens his neck, opens his glottis, and slowly but deeply exhales the air pent up in his lungs. These processes of Pûraka, Kumbhaka and Rechaka, though they do not belong to an independent Prâṇâyâma, should follow all the rules to which ordinary Prâṇâyâma is subject, not omitting the rule which requires 1 : 2 : 2 or 1 : 4 : 2 as the relative proportion of the component parts of a round of Prâṇâyâma.

Whether one Prâṇâyâma should immediately be followed by another with the three Bandhas or the student should take some normal breaths before he begins the next Prâṇâyâma, depends upon the choice and capacity of the student. If necessary he might even let go his hold upon the foot and relax his knee-joint after one Prâṇâyâma is over. It is to be remembered, however, that the longer one retains his hold on his foot and undertakes successive Prâṇâyâmas without punctuating them with normal breathing, the quicker and better is the achievement of the student.

When the student has exhausted half of the energy which he wishes to spend in the practice of Mahâ-Mudrâ, he should resume his normal position and get himself ready for the expenditure of the other half.

The other half of his energy is spent exactly as the first half with this difference. Instead of setting the left heel against the perineum, now the right heel presses that anatomical part (*Vide* Fig. XIV). So also the leg that is kept extended, is the left and not the right. Obviously the left foot is caught hold of in the finger-lock instead of the right. The remaining part of the technique is the same in the second half as in the first

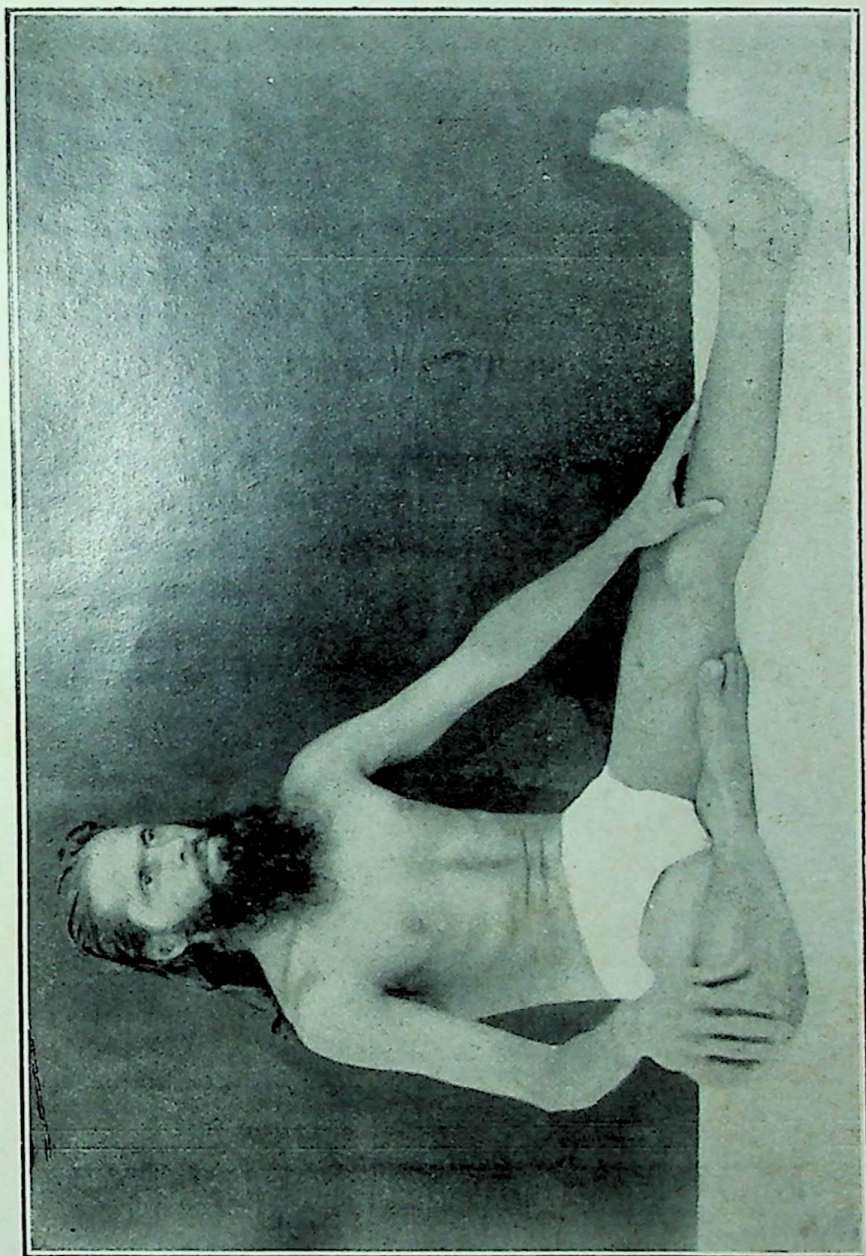
Fig. XIV

The Right Heel Set against the Perineum.

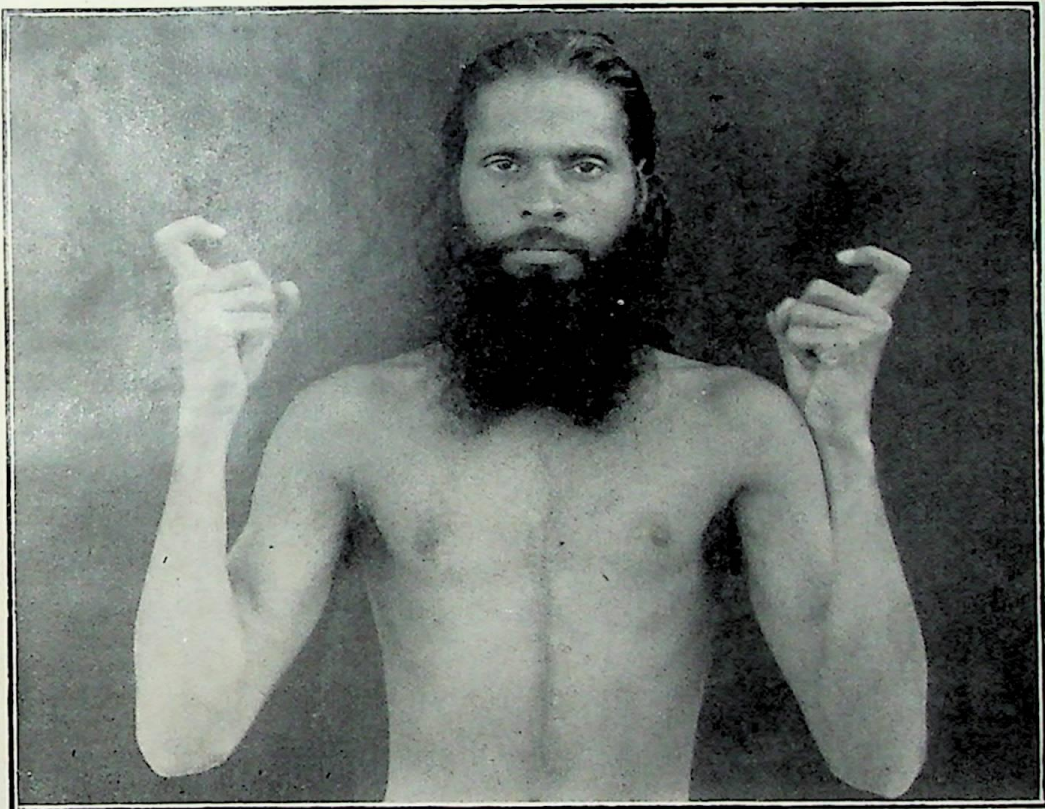
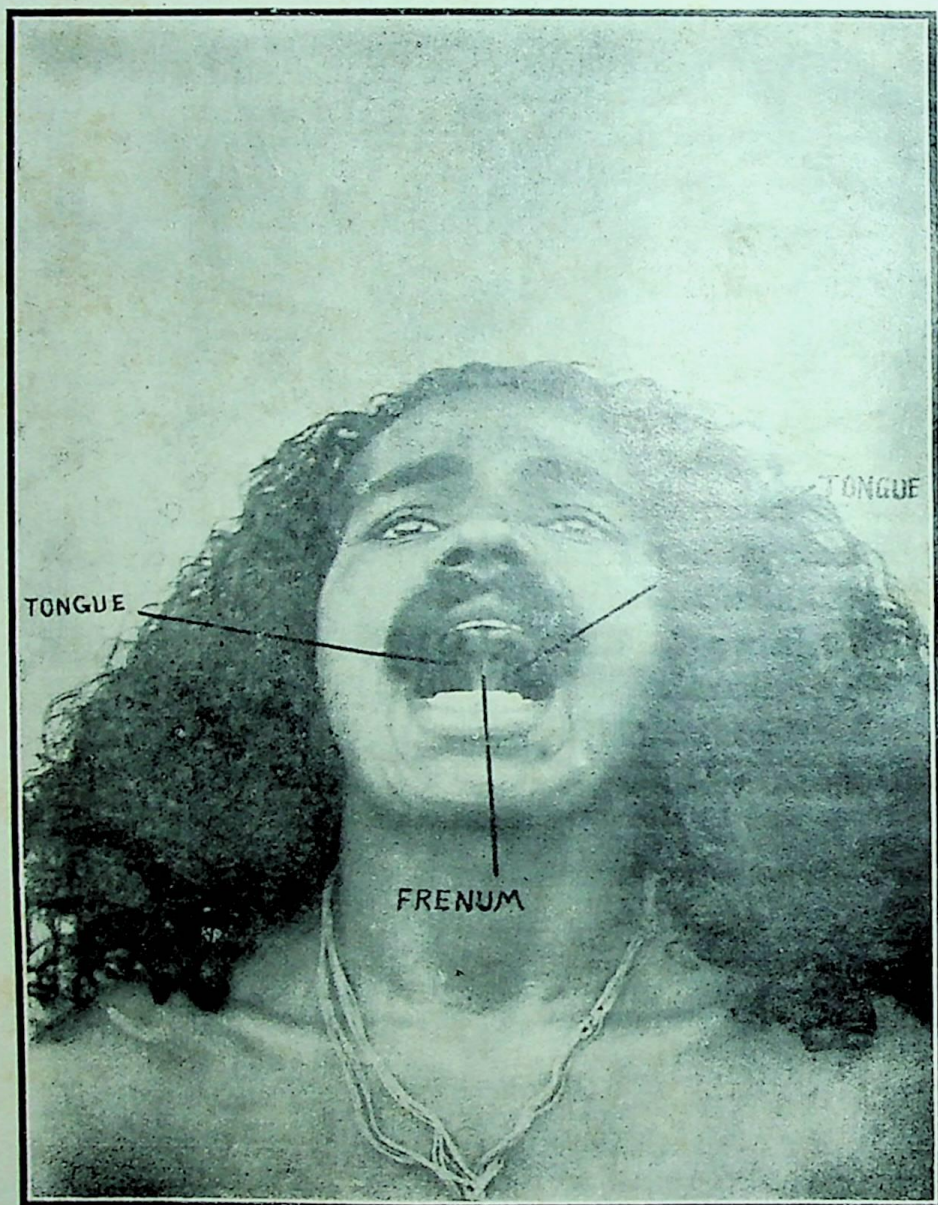
Fig. XV

Hooks of Index Fingers.

Fig. XVI

The Great Toe Hooked in Index Fingers.

Fig. XVII

Jihvâ-Bandha.

half. It is essential that the number of Kumbhakas attempted in the two halves of the practice of Mahâ-Mudrâ, is the same. Needless to point out that this equality in the number of Kumbhakas would be of little use, if the vigour and intensity with which the Kumbhakas are done in the two halves, are not the same. When both the halves are completed the exercise of Mahâ-Mudrâ is finished.

Up to now in our description of the technique of Mahâ-Mudrâ, we have followed our own tradition.[1] Now we wish to point out the variations in this technique according to the different traditions that deserve our attention.

The tradition which comes nearest to ours is that of *Haṭha-Pradîpikâ*. Svâtmârâma Sûri, the writer of this authoritative work, advises only two Bandhas instead of three to be practised while Kumbhaka is being maintained. He omits Uḍḍiyâna. His commentator Brahmânanda who is trained in a tradition which is different from that of Svâtmârâma Sûri, differs from the Mâdhavîya tradition on two important points. First of all he wants the great toe and not the foot of the extended leg to be caught hold of in the hooks of the index fingers and not in the finger-lock. Hooks of index fingers are illustrated in Fig. XV and the great toe secured in these hooks is shown in Fig. XVI. Secondly he advises Jihvâ-Bandha to be coupled with Kumbhaka and not the three Bandhas. Jihvâ-Bandha is to be seen in Fig. XVII, and is described in the third volume on pp. 55-6.

According to the author of *Gheraṇḍa-Saṁhitâ*, another important text-book of Haṭha-Yoga, Mûla and

1 Hereafter our tradition will be designated as Mâdhavîya tradition, because it is handed down to us by our most revered Gurudeva Paramahaṁsa S'rîman Mâdhavadâsajî Mahârâja of Mâlasara.

Uḍḍiyâna do not form a part of the Mahâ-Mudrâ technique. He advises only Jâlandhara-Bandha, the same being, however, characterized by Bhrûmadhya-Dṛishṭi or gazing at the meeting point of the eyebrows.[1] (*Vide* Fig. XVIII).

The tradition of *S'iva-Saṁhitâ*, a third noteworthy text-book of Haṭha-Yoga, stands for the simplest technique. It prescribes only Jâlandhara, omitting both Uḍḍiyâna and Mûla, this Jâlandhara not requiring Bhrûmadhya-Dṛishṭi.

A comparison[2] of the techniques prescribed by the different traditions noted down here, will show that the Mâdhavîya tradition makes the practice of Mahâ-Mudrâ most difficult. The Mâdhavîya technique is, however, the most perfect of the lot. It owes this perfection to the inclusion of Uḍḍiyâna which all other traditions omit from their techniques. Uḍḍiyâna is acknowledged by all Haṭha writers to be of special value in awakening Kuṇḍalinî[3] which is also the aim of Mahâ-Mudrâ. Hence

1 *Gheraṇḍa-Saṁhitâ* does not very clearly say whether the foot of the extended leg is to be caught hold of in the finger-lock or only the great toe in the finger-hooks. The words करे धृतपदाङ्गुलः would mean both, according as we take the word अङ्गुल in the compound to be in the singular or plural. The singular would show that only the great toe is to be hooked in the index fingers, as shown in Fig. XVI. But the plural would mean that all the toes are to be held in the finger-lock. Fig. IX shows the position of the finger-lock when the toes are caught hold of, whereas Fig. X represents the position of the lock, when it takes hold of the foot. In either case the pull must be felt throughout the posterior muscles of the extended leg. The form करे (sing.) is obviously a mistake. It should be करयोः (dual), meaning in *both* the hands and not in *one* hand.

2 It is to be carefully remembered that this paragraph and its foot-note are written in order to institute a comparison between the Mâdhavîya and other techniques of Mahâ-Mudrâ. There is absolutely no intention of comparing either the efficacy or the respectability of the different traditions.

3 There is a special Mudrâ called S'aktichâlana (*S'akti*, Kuṇḍalinî, and *Châlana*, awakening) intended for rousing Kuṇḍalinî. There is also a special practice of Prâṇâyâma, for the awakening of Kuṇḍalinî. When our readers will study the techniques of these exercises in detail, they will find that these exercises have been incorporated in Mahâ-Mudrâ *in toto*. As Uḍḍiyâna forms an integral part of these two exercises incorporated in Mahâ-Mudrâ it is but natural that it should form a part of the Mahâ-Mudrâ technique.

Fig. XVIII

Bhrûmadhya-Dṛishṭi.